UNIVERSITY OF ALBERTA

'OCCASIONING SELVES' IN THE COMPUTER ASSISTED MATHEMATICS CLASSROOM

by

Mary-Lee Judah ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Education

DEPARTMENT OF SECONDARY EDUCATION

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled *'Occasion Selves' in the Computer Assisted Mathematics Classroom* submitted by Mary-Lee Judah in partial fulfillment of the requirements for the degree of Masters in Education.

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For Lionel

ABSTRACT

The purpose of this study was to identify in what ways computer activities contribute to shifts in student attitudes about mathematics. Specifically, the study asked students to reflect on changes in their attitudes following a series of activities where they used computers as, to use Jonassen's (1996) term, "mind tools".

Students completed two spreadsheet activities, one database activity and one PowerPoint activity. The activities were designed to engage students in using the Internet in order to collect data and the four accompanying activities were designed to enable students to classify, sort and analyze data. Examples of students' "cultural artifacts" are used as a means of capturing "student voices" as they were engaged in the study.

In a constructivist sensibility, this study demonstrates that technology is a useful tool for exploring and fostering thought within a larger effort of building cultural meaning "with students" not "for students".

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The Fennema-Shermans scales can be obtained by emailing Cheryle Wampole;
cherylew@soemadison.wisc.edu. You have my permission to use them.At 01:40
PM 2/2/99 -0700, you wrote:
>Dr. Fennema,
>
>I am a graduate student at the University of Alberta and am interested in
>using your scales for measuring attitudes related to mathematics entitled
>"Fennema-Sherman Mathematics Attitudes Scales: Instruments Designed to
>Measure Attitudes Toward the Learning of Mathematics by Females and Males"
>in order to gather information for my Masters thesis. I have yet to obtain
>a copy of the scales and would like to know: 1) How can I obtain a copy of
>your scales?, and 2) How can I obtain permission to use your scales?
>
>Thank you, in advance, for your help with this matter. I greatky
>appreciate any assistance you can offer me.
>
>Regards,
>Mary-Lee Judah
>

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I. THE PROBLEM

Introduction

I recall vividly my first encounter with computers in the classroom. One of the first questions I asked after being hired to teach in a grade two French immersion classroom was, "Does this school have a computer lab?" The principal beamed as he led me to the new computer lab containing twenty-four new Apple IIes. I was more than glad to see these computers as they were ones with which I was familiar, and I knew that I would use them for my geometry section by having the students create geometric figures using Logo. After two years, the Apple IIes were removed and, thus, so was my access to Logo, leaving the students with nothing more than word processing and limited graphics capabilities. There was a shift from Logo to information processing where students starting in grade three would spend twenty minutes a day learning how to keyboard.

Almost ten years later, there have been more major changes in the use of computers. Today, students are expected to use computers in order to perform a number of tasks from information processing, to pattern recognition to engaging in "experimental" mathematics, to data collection, to data organization and on to data analysis. As I see the changes that have occurred, students are now being asked to "do something with" a computer rather than having the computer "do something for" the student. There is an intuitive sense that, somehow, computers do enable us to do more. The question is more of what? The promise and challenge of using computers in the classroom have challenged much of my own teaching. Like many teachers, I have struggled to locate a meaningful place for computers in my teaching.

The use of computers as a teaching tool has become more commonplace during the last decade. Technology, according to the *Information and Communication Technology, K -12: An Interim Program of Studies* (1998) (ICT) is something that teachers already use in order to do their jobs. The ICT posits that technology "is more pervasive today than it has ever been" (1998, p. 1). In the province of Alberta, outcomes for student learning include the use of computers as an integral part of the teaching curriculum for all core subject areas. Although I do acknowledge that remarks that exalt the virtues of technology are rather exaggerated, technology does indeed have its place within the classroom and within the curriculum.

As I will argue throughout this study, I believe that the best application of computers in the mathematics classroom, or in any classroom, is one that is technology enabling. Perhaps because of its computational nature, mathematics is an area where there has been an increasing amount of pre-packaged software, such as Data Explorer (IBM) and the ITP Nelson series, made available to teachers as a means of integrating computers into the curriculum. Teachers should, therefore, be aware of how software programs might fit into the curriculum as well as be aware of possibilities for integrating computers in various ways. As a colleague told me once, "We need to be drivers, not driven, and mechanics, not mechanistic, if we are going to use computers effectively in the classroom."

Technology Integration into Mathematics: An Overview

The National Council of Teachers of Mathematics (NCTM) and Alberta Education have adopted similar assumptions about learners that influence mathematics education and the incorporation of technology as tools for mathematical instruction. Both these organizations share a commitment to constructivist assumptions about teaching and learning (NCTM, 1998, 1991, 1989; Alberta Education, 1998). Those that claim to be constructivists represent a wide and diverse group. Later in this study, I will define the term more precisely. For my purposes now, it is sufficient to say that constructivism advocates that learning is the process of adaptation between the world as given and the learner's past experiences (von Glasersfeld, 1990). Constructivism rejects realism per se. The notion that there is one way to represent the world is, therefore, cast aside (Davis, 1995, p. 33). In documents published by the NCTM and Alberta Education, the use of technology for teaching includes the use of calculators, computers, micro-based laboratories and web browsers (NCTM, 1998, Alberta Education, 1998).

Constructivist theorists (Bruner, 1996; Ritchie & Baylor, 1997; Vermulen, Volman & Terwel, 1997) argue that students should be made aware of the proper use of technology and should be guided in deciding which tool is the most useful to complete a given task. Such reasoning becomes an important part of teaching mathematics because students need to consider whether choosing a paper and pencil to resolve a problem is more appropriate than entering the data into a calculator or a computer. Technology, I argue, should allow students to broaden ways in which they view possibilities. Beyond this scope, students can use computers to investigate such concepts as fractal patterns in nature – a task that is next to impossible without the use of computers due to the cumbersome task of manually producing one representation versus innumerable representations. Students are thus able to concentrate on other mathematical processes which are necessary in order to complete a given task (NCTM, 1991). The teacher's role when integrating technology into the classroom becomes one of facilitator and director rather than the owner of knowledge; therefore, it is the teacher's interactions and prompts based on their understanding of the content rather than the specifics of that particular content become a crucial component of the classroom. Obviously, this is not a new approach for teaching in any subject area, as can be concluded by the wide acceptance of the NCTM Standards by Canadian teachers as well as American teachers.

I believe that teachers can use constructivist approaches in their classrooms without using computers. There can be little doubt, however, that the use of computers in the classroom presents unique opportunities for teachers who are committed to constructivistic learning strategies. A look at the implications of computers and constructivism is necessary in order for educators to implement computer usage in the mathematics classroom while maintaining the integrity of constructivism. In particular, I would argue that technology integration informed by constructivism offers mathematics educators opportunities to capitalize on what Boudourides (1998) underscores as the inherent "interpretive flexibility" of computers in the classroom (p. 9). As Boudourides suggests, while technologically oriented people may be largely unconcerned about any one particular learning model in the classroom, teachers can draw much from constructivist approaches that see computer-mediated instruction as an opportunity to enrich the mathematical representations created by students.

The use of technology in teaching mathematics can empower students to become better problem solvers and to become less afraid of taking risks. Students need to be "exposed to technology because they need to be exposed to change, to be flexible problem solvers with reasoning skills" (Hill, 1995, p. 25). I argue that students need more than exposure to technology; they need to be taught how to evaluate its usefulness in a given situation and to apply its use to new situations. These two considerations make the role of the teacher a critical one; teachers should learn how to teach mathematics while enhancing the student's learning through the use of technology. In a constructivist sensibility, technology is a useful tool for exploring and fostering thought within a larger effort of building cultural meaning "with students," not "for students."

An Overview of the Study

The ICT released by Alberta Education in 1998 mandates the use of technology across the curriculum in all grade levels. The implications of this document in any given subject have yet to be assessed, as does the question of how technology will be implemented in any given subject area. My research aims to raise questions as to how the use of computers, in a particular way, affects students' attitudes and self-efficacy within the context of a grade eight mathematics classroom. I will also examine how computer integration raises pedagogical issues for the ways in which teachers organize their relationships both with students and instructional processes. In order to better understand students' attitudes and feelings of self-efficacy towards computers and mathematics, two teachers from Central Alberta collaborated with me in the teaching of a series of computer-mediated mathematical activities that included Internet research, spreadsheets, databases and a multimedia presentation activity (Appendix A). The unit of instruction took approximately two months to complete as visits were limited to once a week. Throughout the course of the activities, students made critical personal choices in developing a travel itinerary for an imaginary trip to two different cities in two different countries. Given a limited budget, students were required to make informed choices about their travel plans and personal priorities while traveling abroad. The activities the students completed drew upon a broad spectrum of their cultural backgrounds and experiences. The culminating activity of a multi-media presentation served as a means to allow students to synthesize and analyze information contained in spreadsheets and databases.

Activity one was designed to increase students' awareness of exchange rates between Canada and five countries of the student's choice by having students create a spreadsheet that converted any given amount of money. Activity two was designed to assist students in further research into the area of currency exchange by providing the students with hyperlinks to various on-line catalogues from different countries. Activity three involved students collecting data regarding exchange rates, the need of a visa or passport for travel and any immunization requirements for travel to five given countries and the average costs of such things as meals and accommodations. The data archived is now accessible to students in future years so that they might be able to analyze fluctuations in exchange rates and costs of travel. As a culminating activity, students prepared and presented a PowerPoint presentation of a trip that they took.

The initial purpose of this study was to investigate the implications of the activities I created in the classroom environment. As the research evolved, the purpose was refocused to reflect activities which the students found to be most engaging as well as investigating how students perceived that mathematics became easier or harder as a result of using computers. Included in the refocus was investigating the possibility that students who did computer activities in the mathematics classroom could undergo changes in attitudes towards mathematics and their feelings of self-efficacy. In order to address the areas of investigation, the following questions were investigated: first, given the unit of instruction I created, did students' expressed attitudes and feelings of self-efficacy towards i) mathematics and ii) computers change from their expressed attitudes and feelings of self-efficacy prior to the unit of instruction? Second, what reasons did students give for changes in their attitudes and feelings of self-efficacy? Third, which of the activities did students report enjoying the most? Fourth, what did students say about how mathematics is made easier or harder for them given the use of the computer for this specific unit of instruction?

Students were interviewed to identify specific activities that engaged them in the most significant ways. Specifically, the study asked students to reflect on changes in their attitudes following a series of activities where they used computers as, to use Jonassen's (1996) term, "mindtools," and the teachers were asked to reflect upon reasons they saw shifts occurring.

Throughout the course of the computer activities, the focus was to use computers as "mindtools"; however, the intent of this study was not to access the effectiveness of these learning strategies in terms of improving student learning and achievement. Rather, this study, as originally conceived was limited to an analysis of attitudinal shifts towards mathematics but it became evident after the first classroom session that attitudes where only one area of the affective domain. By concentrating on this one area, the richness offered by the learning environment would have been lost by having such a one-dimensional focus.

I was present in the classroom along with the classroom teachers to facilitate the teachers' use of the computer activities. My primary objective was to note student comments and behaviors as they related to their affective engagement and to assist students with using the computer in ways appropriate to the activities.

The intent of this study was to add an important element of using "mindtools" to develop critical thinking (Jonassen, 1996). While Jonassen has made an important contribution to our understanding of the critical and intellectual components of student learning, he has not sufficiently elaborated on the emotional and affective dimensions of the student's world. "Mindtools" are an important pedagogical contribution and there can be no doubt that Jonassen's work will inform classroom practice. It is my argument that, in order to fully realize the potential of Jonassen's work, we must pay attention to the role of emotional investment in mathematics. Indeed, as Jonassen argues, a growing challenge for teachers in the classroom are the issues of commitment and authority as they relate to learning while using computers (p. 266). My research intends to fill the gap left by Jonassen by identifying general ways in which students use computers that contribute to changes in students' attitudes toward mathematics as suggested by the *Fennema-Sherman Mathematics Attitudes Scales: Instruments Designed to Measure Attitudes Toward the Learning of Mathematics by Females and Males (Fennema-Sherman Scales)*. By reflecting with students on particular computer applications that contributed to student involvement in spreadsheet, database and multimedia presentations, I have attempted to identify features of these computer activities that may be related to changes in a particular cohort of students' attitudes and feelings of self-efficacy toward a particular subject, in this case mathematics.

Significance of the Study

The ability of a student to acquire technology skills is a process outcome in the ITC (1996, p. 2); the integration of computers into the classroom forces the teacher to implement new strategies and to reevaluate personal teaching beliefs. Research is needed to indicate how the uses of different innovations in the classroom are implicated with attitudes of students as well as their feelings of self-efficacy; this study attempted to do so. I propose that computers, used in a constructivistic way, is one of the innovations that can affect students' attitudes and their feelings of self-efficacy in the mathematics classroom. By engaging the questions I raised in this study, teachers will have the opportunity to use the information included in the study to more adequately incorporate computer usage into their classrooms.

The study further aims to help educators recognize different ways for integrating computers into the classroom of which they were perhaps unaware. Given that the activities are designed to engage students in the process of computer use in mathematics, participating teachers were able to explore ways in which computers in the mathematics classroom creates possibilities for enhancing ways that students think about their abilities and engagement with mathematics. At the same time, this study will allow educators to review a series of activities that enable students in learning mathematics in an integrated manner by using computers. This study does not claim to offer a prescription or a "model" for instruction with computers; rather, it simply seeks to identify possibilities for improving student attitudes toward mathematics and their feelings of self-efficacy.

Key Definitions and Concepts

Attitude

Attitude refers to the manner or the disposition of a person towards another person, a situation or an object (Urdang, 1968, p. 87). For the purpose of this study, attitude refers to positive (like) or negative (dislike) feelings students have towards mathematics and computers.

Mindtools

Mindtools refers to the use of computers in a way that allows students to explore and construct meaning that is relevant to them. Jonassen (1996) describes mindtools as opportunities for integrating broader senses of what it means to be a learner (p. 64). As he argues, "learners are actively engaged in learning rather than merely reading or responding to questions, they are actively building knowledge structures because they are actively engaged in knowledge representation activities" (p. 65).

Self-efficacy

Self-efficacy is the confidence people have in their ability to perform certain tasks. Self-efficacy, therefore, impacts upon the attitudes and feelings towards such things as a school subject. Self-efficacy is inextricably linked to attitudes. Bandura (1977) views self-efficacy as the middle space between a person and behavior.

Technology

Technology for the mathematics classroom refers to hand-held calculators, graphing calculators, computers, micro-based laboratories, software and web browsers.

Delimitations of the Study

This study is delimited to the specific activities designed by the researcher to accommodate the division three (grades seven to nine) learner outcomes for technology and mathematics students in the province of Alberta; they represent an example of the use of computers in the teaching of mathematics and are intended to address the specific technology learner outcomes:

- Design, create and modify a spreadsheet to calculate currency exchanges.
- Design, create and modify a spreadsheet for a specific purpose, using the functions of quotient, product and difference.
- Use the graphing tool in "Excel" to create a graph based on one variable.
- Use a computer to solve a problem involving rational numbers.

- Modify an existing database for a specific purpose: to organize information related to travel and exchange rates.
- Make connections among related, organized data and assemble various pieces into a unified message (Alberta Education, 1998).

The specific mathematics outcomes for grade-eight include the following:

- Select, define and use appropriate methods of collecting data.
- Apply percents greater than one hundred in decimal form.
- Compute and verify the quotient of rational numbers using decimal representations.
- Display data by hand or by computer in a variety of ways.
- Use concepts of percents to solve problems in meaningful ways (Alberta Education, 1996).

This study only represents three applications of computer activities in mathematics education, specifically spreadsheets, databases and multimedia presentations. The conclusions represented should not be generalized to use of other computer applications or to broader mathematics education.

Although the activities that have been created are interdisciplinary in nature, I have chosen only to analyze responses that are related to mathematics and computers.

This study is an analysis of changes in student attitudes and feelings of self-efficacy toward mathematics in the context of a series of particular activities. In no way has this research attempted to make claims as to the efficacy of "mindtools" as an enhancement of cognitive ability. This study does not undertake to measure improvements in student learning; therefore, in this regard, objective assessment instruments and baseline measures of the study group as compared to control groups will not be administered.

Classroom observations were only conducted in a mathematics classroom in which the students used the researcher's computer activities; therefore, no comparisons are made between attitudes or feelings of self-efficacy of students who completed the same types of activities without the use of computers.

Limitations of the Study

The teacher involved with this study had previously completed a spreadsheet activity and a multimedia presentation involving students analyzing data within a spreadsheet and allowing students to create their own multimedia presentations. The students, therefore, had some, albeit limited, previous experiences with computers and computer-mediated instruction. This fact had some effect upon attitudes they have established towards the use of computers in general.

Students completed the spreadsheet and database activities with the researcher present; thus, student responses and behaviors may have been influenced by the change in classroom dynamics.

Interpretations are confined to responses collected regarding the specific activities during this specific research period, as the data collected is context dependent to one particular classroom in one particular school. Additionally, the students' ability and willingness to respond to the researcher limit the research.

As the study is a comparison of students' attitudes before and after the use of computers in the mathematics classroom, students were invited to include their names or pseudonyms on the survey instruments so that changes can be assessed. Students may, therefore, have been reluctant to divulge their true sentiments towards certain questions.

This study is limited by the form of data that can be collected through the survey instrument used, interviews, observations and teacher reflections.

The students' use of computers is limited by the operating capacities of the technology available in the school and the software available. For the purpose of this study, a PC platform was used as well as the following software: Excel for the spreadsheet activities, ClarisWorks for the database activity and PowerPoint for the multimedia presentation.

Thesis Overview

Chapter II of this thesis will deal with investigating literature that is related to mathematics, technology, constructivism and attitudes. Chapter III focuses on the methodology that was used in this study. In order to accomplish this, the following are included in this chapter: a description of the methodology used, data collection techniques, a description of the research perspective, an outline of the research process and issues surrounding the research. Chapters IV and V will discuss the results of the activities as well as how the students undertook the problems and the activities associated with this study. Chapter VI addresses the issues that arose during the course of this study as well as the implications for computer use in the classroom and its effects on attitudes and students' feelings of self-efficacy.

II. REVIEW OF THE LITERATURE

Introduction

The field of mathematics and its instruction has undergone a massive shift during the past ten years. Take, for instance, the description of school mathematics adopted by the NCTM as presented in the *Professional Standards for Teaching Mathematics* (1991) and the *Standards for Teaching Mathematics* (1991, 1995), which suggest that students learn mathematics by becoming actively involved in their learning and, thus, construct understanding of mathematical concepts by internalizing new information. Mathematics is no longer a subject where a student is expected to perform basic computational skills but rather becomes a tool for problem solving, communication, reasoning and making mathematical connections (NCTM, 1995, p.1). As a consequence, teachers are experiencing a philosophical shift away from traditional drill and practice methods of instruction to one where the learner engages in manipulating and transforming data, as well as creating and generalizing abstractions, through the use of a number of different strategies and models (McCoy, 1996, p. 438).

In a NCTM document entitled *Standards for Mathematics* (1995), new goals for students regarding the learning of mathematics are outlined. It is through these goals that the link of the NCTM philosophy with constructivism is implied. The NCTM has established five general goals of student learning for all students as follows:

- they learn to value mathematics
- they become confident in their ability to do mathematics
- they become mathematical problem solvers
- they learn to communicate mathematically
- they learn to reason mathematically
  (*Curriculum and Evaluation Standards*, 1989, p. 4)

In the province of Alberta, Canada, Alberta Education has used the NCTM *Standards* as a basis for the development of a new mathematics curriculum entitled *The Common Curricular Framework for K-12 Mathematics: Western Canadian Protocol* (WCP) *for Collaboration in Education* (1996). Keeping with the Alberta Education philosophy of ongoing curriculum review, the mathematics curriculum was revised to ensure that students graduating from Alberta schools gain the necessary skills to meet with success in "post secondary institutions and the workplace" (*The New High School Math Program Student/Parent Handbook*, 1998, p. 2). The handbook explains the importance of students becoming better problem solvers both within and outside of the area of mathematics and effectively using information technology (p. 2). Alberta Education (1996) has set the instruction of information technology as one of the goals of *The Common Curriculum Framework for K-12 Mathematics*.

The "Emergences" of Constructivism

In its basic formulation, constructivism assumes that learning occurs when there is a partial discrepancy between what a student already knows and what the student confronts (Sparks & Hirsh, 1997, p. 9). According to Brooks and Brooks (1993), when a learner is confronted with such discrepant data or perceptions, the learner either interprets new information within a "present set of rules for explaining and ordering the world," or the learner "generates a new set of rules that better accounts for what is perceived to be occurring" (p. 4). Rejecting the notion that knowledge is an inert object to be transmitted from teacher to students, constructivism assumes that learners formulate, as active and engaged learners, cognitive schemas that act like maps of the world (Clinchy, 1995). Without opportunities for students to make adaptive changes to their world of knowing, learning remains imitative and deficient.

Broadly informing emerging trends such as whole-language, manipulative mathematics programs, cooperative learning, and constructivism locates the teacher-as-learner in the classroom. The teacher is no longer the sole possessor nor conveyor of knowledge. Rather, the teacher and students enter into a symbiotic relationship where they are both possessor and conveyors of knowledge. The implications of constructivism, in this research, into the integration of computers into the mathematics curriculum are underscored by the central location of teachers-as-learner (that is, seeing teachers as actively engaged partners, with students, in the building of ways of knowing). I will argue that, when teachers move to integrate technology into the classroom, they have a real opportunity to move from traditional "instructivistic" or "didactic" models of teaching to an approach that draws on computers as tools which will enhance meaning-building with students.

Brooks and Brooks (1993) argue that innovations and change are the vehicles through which teachers enter into a new relationship with their students and the curriculum. As technology and alternative interpretations of what is "worth knowing" enter educational debates, there can be little doubt that constructivism as a methodology for planning instructional sequence is one in which the student and teacher build knowledge and learning together. Indeed, as Brooks and Brooks remark:

> When students work with adults who continue to view themselves as learners, who ask questions with which they themselves still grapple, who are willing and able to alter both content and practice in the pursuit of meaning, and who treat students and their endeavors as works in progress, not finished products, students are more likely to demonstrate these characteristics themselves (1993, p. 9).

The foundation for conceptualizing how constructivism informs our understanding of how technology integration occurs in the mathematics classroom cannot be concerned only with how students come to know the world, it also needs to examine issues surrounding how teachers see themselves as learners coming to know the world. Teachers need to become active participants who "are given ample opportunities to learn in constructivist settings and construct for themselves educational visions through which they can reflect on educational practices" (Brooks & Brooks, 1993, pp. 121-122). The following discussion underscores how constructivism is a basis for educational researchers from which to understand technology integration as an opportunity to move teaching practices away from instrumentalism towards approaches that are attentive to the way students construct personal understandings of the world in which they live.

"Construction Zone": Making Meaning

The emergence of constructivism in educational research and as a philosophical basis for curriculum and policy is part of a growing recognition that previous learning theories that dichotomize "brain" vs. "environment" fail to successfully link "mind" and "culture" in a synthetic way. In a constructivist approach, there is a shift towards seeing knowledge as a highly relational and organic process of the co-emergence of teaching practice and theory. Recently, in *The Culture of Education*, Bruner (1996) made a daring attempt to bring together the myriad of assumptions about learning in a synoptic analysis that defends his case for "culturalism" (p. 3). Generally conceived, culturalism is a theory of learning that views the contributions of previous models (such as information processing with its computational view of "mind") as offering a partial but not totally incorrect understanding of learning. Challenging the ideas of the computational metaphor of the mind was, for Bruner, one of many efforts by theorists to critique others who attempted to contain "mind" to one single representation. Not fearful to take on the formal structuralists and hard-nosed cognitivists such as Artificial Intelligence (AI) modelers himself, Bruner is equally unforgiving toward the radical social constructivists who subscribe to hermeneutics and other "high-brow interpretative pursuits" that often turn away from dealing with pressing technical social problems (p. 6). While the stricter cognitive-structuralists who support information processing models of learning may be at odds with personal meaning-making and hermeneutic traditions, Bruner argues that there are ways for education to learn from all models of learning since "all-or-none and once-for-all theories of mind are not educationally interesting" (p. 8). Bruner's increasing use of social constructivistic theory, one he labels as "culturalism," represents a synthesis of curriculum thinking that allows us to come to terms with the ways teachers adapt to technology in their classrooms and with ways that Vygotsky frames the learning student as always functioning slightly "beyond" him/herself.

Bruner's (1996) culturalism allows us to see how different ways of imagining the learner represents gateways through which mathematics teachers pass in their daily interactions with students. Bruner's synthesis is a theory both about how students learn and how teachers teach. It is a theory that has two tasks:

> On the "macro" side, it looks at the culture as a system of values, rights, exchanges, obligations, opportunities, power. On the "micro" side, it examines how the demands of a cultural system affect those who must operate within it. In that latter spirit it concentrates on how individual human beings construct "realities" and meanings that adapt them to the system, at what personal cost, with what expected outcomes (p. 12).

Bruner's move from an interest in strict cognitivism has not been one of abandoning one theory and appropriating another. Rather, Bruner's shift in orientation emerges from his growing interest in how children enter a world that has an existing language and culture in place for them. While cognitivism tends to focus on the latent structures in the minds of children, Bruner (as cited in Papp, 1996, p. 349) has increasingly emphasized the view that children are continually "constructing and reconstructing meaning." For Bruner, success in the schoolroom depends on our ability to understand and contingently apply alternative models of human development and learning that attends to the child's "culture in mind." Bruner's synthesis is important for understanding technology in education because he illustrates how meaning is co-emergent within "culture-in-mind." Consider Bruner's (1996) claim that:

> The forms of meaning making accessible to human beings in any culture are constrained in two crucial ways. The first inheres in the nature of human mental functioning itself... The second comprises those constraints imposed by the symbolic systems accessible to human minds generally – limits imposed by the very nature of language – but more particularly, constraints imposed by the different languages and notational systems accessible to different cultures (p. 18).

For Bruner, the dominant learning metaphor is that of a child put into a play; children may not know what the play is about but, through the process of engagement with the narratives given to them, they formulate "acts of meaning" that work for them (Bruner, 1990). From a cognitive growth model has grown the broadly defined community of theorists labeled "constructivists," who share a belief that "knowledge is always an answer to one's own question" (Sierpinska, 1997, p.23).

Constructivists believe that a student observes information, internalizes data, and makes generalizations about mathematical processes in the real world. These generalizations emerge within the context of the learning experiences provided through interaction with problems that are characterized by Bruner's notion that we learn when we want to get "unstuck" (Bruner, 1996, p. 52).

The emergence of social constructivism is part of a growing acceptance that the learning theories and teaching models of the past fail to successfully link "mind" and "culture" in a synthetic way. The information processing and behaviorist models emphasize "cogito" while the social interaction and personal models tend to privilege the ego, the self, as a unit of understanding. While these models of learning do help teachers teach, by themselves they do not give a practical way of bridging the split between "mind" and "culture," between what is inside and outside the learner. For Bruner, cognitivists who theorized about "mind" failed to acknowledge the analogy that "mind always exists in culture and culture lives in mind." Destabilizing the cognitivist's dream of "getting at mind" was Bruner's major impetus in *The Culture of Education.* Bruner argues that interpretation is neither representation nor a mere artifice of the individual mind or "cogito." Unlike other creatures, humans possess "culture in the mind." In short, constructivism provides us with a way to envision the mind and culture as an enfolded antinomy. The mind-in-culture antinomy is Bruner's (1996) seminal contribution to education.

The Mobius strip can provide the topology of mind towards which Bruner is working: a two-dimensional surface that creates an enfolded third space. Here, culture and brain form a nexus of "mind": a third place called the student's mind. In Bruner's view, the schoolroom is "situated in a broader culture" - a reality that frustrates theoreticians who would prefer life not to be complicated by the living. Sensitivity to the prevailing wisdom of a culture is needed if one is to understand "other minds." A constructivistic approach to learning engages a child's movement from a naive realism (that the beliefs one holds reflect the reality of the world) to the development of an ability in children to think about their thinking (Bruner, 1996, p. 49). Critical is Bruner's claim that we should not confuse "doing" with "understanding" (as do proponents of information processing or behavioral models of learning). The classroom implications of a constructivist approach are innumerable. According to Kieren (1995), the teacher should take on the role of facilitator (where the teacher's teaching moves from teaching from the front of the classroom to teaching from the side). Kieren's position is supported by Jonassen (1996), who argues that teachers must:

- relinquish some power related and intellectual authority in the classroom
- accept different perspectives that might challenge the teachers
- develop and use alternative assessment methods and criteria (p. 266).

McWilliam and Taylor (1998) argue that constructivism is an important entry point for engaging teachers about decisions they make regarding how they conceive "how students learn." By focussing on teachers' assumptions about what knowledge (if any) students bring to the classroom, constructivism encourages teachers to imagine learning as a highly relational activity between the deep structures of "cognitive" and surface structure of the "social" (Ramsden, 1992). Vosniadou (1996) argues that constructivism offers for teachers a new understanding of learning that sees the mind

> not as an individual information processor, but as a biological, developing system that exists equally well within the individual brain and in the tool, artifacts, and symbolic systems used to facilitate social and cultural interaction (p. 95).

As we move down the continuum from information processing (by implication, being driven by the power of computers) to personal models of learning (that see computers as enabling), we see an equivalent parallel transition from an understanding of "other minds" that moves from a cognitivistic to a constructivistic orientation. The images of "other minds," Bruner suggests, are not wrong, they are simply incomplete.

Like other defenders of constructivism who turn away from focussing on getting "pure knowledge" into the heads of children, Bruner (1996) believes it is more desirable to operate within an approach that sees knowledge as building a story, constructing a narrative. The irony is that, just as we construct metaphors of mind, the images we come to construct and reinforce teaching through practices, in turn, become justifications for our assumptions about learning. Von Glasersfeld and Steffe (1991) recognized the implications of teacher philosophies in a constructivist classroom and explored how mathematics teachers come to construct models of how students' minds work.

I would claim that this analytical move in mathematics education to describe the emergence of teacher knowledge (or stories about "other minds" as Bruner would frame it) represents a shift towards seeing pedagogical knowledge as a highly relational and organic process of the co-emergence of teaching practice and theory. In other words, given the relational nature of mind-in-culture that Bruner (1996) posits, how does constructivism connect not only with mathematics education but also with the formation of teachers' models of "other minds"? As well, what are the implications of Bruner's work in laying out the possibility that computers can become "enabling" opportunities in the classroom?

Bruner poses two questions that form the basis for any sound curriculum: "1) What do we do when we get stuck? 2) What are the problems we run into in getting the knowledge we need?" (p. 52). These two questions could be on the archways of any mathematics classroom that claims to draw on the broad impulse that is constructivism.

Relating Bruner's questions to mathematics, Dehaene (1997) suggests that mathematics is always learned within a socio-cultural context in that

> constructivists believe that mathematical objects are nothing but constructions of the human mind. In their view, mathematics does not exist in the outside world, but only in the brain of the mathematician who invents it (p. 243).

Complementary to Dehaene's view that the learner invents mathematics, Einstein suggests that mathematics is learned through personal creations. Time and time again, Einstein commented that his greatest breakthroughs were achieved through visual metaphors rather than the strict realism of mathematical formulation; the imagery preceded mathematical representation (1905). As Einstein stated, "When I examine myself and my methods of thought, I come to the conclusion that the gift of fantasy has meant more to me than my talent for absorbing knowledge" (as cited in Presmeg, 1997, p. 301).

The constructivistic sensibility thus implies that within each of our own relations with our worlds emerge the questions that become the beginning of knowing. A microworld is a relationship of variables within a given environment (Leron and Hazzan, 1997, p. 19:4). A microworld is an analogue that reflects the world and allows the learner to view how it operates. By doing this, you can link the operating principles the sample of the world uses in order to make inferences of what happens in the world as a whole.

There are three characteristics of microworlds that are necessary for teaching using a constructivist approach. As suggested by Leron and Hazzan (1997), these characteristics need to be purposefully built into the computational environments as they do not occur on their own in natural environments. Firstly, microworlds must have built in constraints that are a source of enablement and limitations. Certain knowledge elements must be built into the microworld that reflect the difficulties presented by the larger outside world. The built in constraints are made accessible to the student through using tools to enhance their learning. Secondly, emergent mental constraints must be established so that the activities do not overpower the learning. A common fault in designing computer mediated instructional activities is mistaking activity for learning. Students who are involved in pressing a computer button a certain number of times before the right answers are given to them, or students who are sitting at a computer terminal clicking the mouse, are not necessarily engaged in meaningful learning. Thirdly, constructed comparisons must be established. Rather than a linear progression of moving from parts to a whole, successive refinement is required in which the "whole" is presented in each part of the learning activity. Students are required to think about what the outcomes of their investigations are before the teacher generates closure in the instructional activity. By achieving these three characteristics, successive refinement is achieved. This parallel's Kieren's sense that teachers ought to "help students bring forth, and to bring forth with students, a world of mathematical significance" (1995, p. 5).

Mathematics within a Constructivistic Context

I would argue that mathematics needs to move beyond the antinomy of the "individual as mind" and the "social as world" in order to reflect the changing view of how students learn. Cole and Wertsch's (1998) suggestion that "mind is distributed" throughout the artifacts and artifice of culture (p. 1) supports my view. Mathematics instruction can lead to the house of cultural knowledge becoming more available to the population. Therefore, the implication for mathematics education is that the relational aspect of learning is of primary importance. High school mathematics, which has traditionally been limited to fewer students than such subjects as English and Social Studies, has not needed to take into account the students' varied backgrounds. As more students begin to participate in mathematics classes, students' cultures must be recognized and accommodated. Such a position is supported by Cole and Wertsch's debt to Vygotsky's possessive framework of the "zone of proximal development" that claims that social interaction is not a direct, transparent, or unmediated process. Instead it takes place in an artifact-saturated medium including language (Cole & Wertsch. 1998, p. 7). As the culture of the students broadens, so does the range of methodology that must be used in a classroom in order to acknowledge and take advantage of the zone of proximal development.

My research assumes the stance taken by Vygotsky (1987) that, as learners, we are implicated in a process of appropriating cultural artifice (such as concepts and formulas) in order to engage the world. Learners are, as Vygotsky declares, social actors whose cognition cannot be compartmentalized into distinct categories such as "individual mind" and "the social." For Vygotsky, meaning is always implicated within the framework of "verbal thinking" (Vygotsky, 1987, p. 47). Vygotsky's notion of "the zone of proximal development" flows from his assumption that learners are always performing beyond their level of competence (in a strict sense of truly understanding what inter-mental processes they are using) because they are like all social actors, able to function in an artifact saturated world that behaves as if they are "truly capable and confident" (Vygotsky, 1987, p. 47).

For me, the implications of Vygotsky's work are central within the current debates in mathematics education. An example is the debate over the use of calculators in the classroom. Rather than defend a pro or con position vis-à-vis the use of calculators in the classroom, one could draw on Vygotsky's (1987) notion that cultural artifacts, in this case calculators, neither deterministically create nor destroy cognition; rather, they simultaneously enable and limit learning. In this sense, I would argue that students come to possess basic mathematical knowledge within their use of the cultural prosthesis that calculators represent. It follows that students can learn to make connections to new ideas and significations of learning for themselves when entering numbers on a page or into a computer within the limits of a culture that knows itself through these self-same tools (calculators and other so-called computational aids).

It is evident that there has been as increasing acceptance of the view that mathematics learning occurs within states of its context or situation as well. Cobb, Wood & Yackel (1991) have articulated the conceptualization of mathematical education within a model that sees mathematical knowledge and cultural artifice as inextricably linked. We cannot think of human agency as distinct from technology. Bauersfeld (1992) and

Cobb (1990), advocate a "mathematico-anthropological context" in teaching where mathematics and culture play equally important roles.

With the curriculum changes that have occurred in mathematics, there have also been changes in the way technological tools are used to learn mathematical concepts (Alberta Education, 1996, NCTM, 1995). Based on my experience as a classroom teacher, I have perceived a gradual shift from a total objection, by both parents and teachers, to the use of any form of technological assisted mathematics to a growing acceptance of the use of calculators and computers as more commonplace. The acceptance has not been one that has occurred with any degree of immediacy.

Like many reforms in education, reform takes place over time. It can be argued that it is research that influences changes in the curriculum. Fullan (1997) postulates that the institutional change cycle can take as long as eight years to occur while politicians who mandate major reforms tend to do so in three to four year cycles. I argue that curriculum change is not only fostered by the influences of research and politicians, but also by public pressure as evident by recent events[1] in Alberta regarding the implementation of the new mathematics curriculum.[2] After initial resistance to the use of calculators in the mathematics classroom, calculators are now more readily accepted as both a teaching and learning tool (Alberta Education, 1998). I see a parallel between the past resistance to the use of calculators to the present resistance to the use of computers in order to realize that the use of computers as a teaching tool in mathematics will ultimately become accepted.

Through the past decade, the application of computer technology in classrooms has moved through a series of transitions. The role of technology has changed from a number processor and data processor (a tool that "crunches" numbers), to an information processor, through to an interactive information processor and an interactive information processor (a source of information) (Papert, 1992; Van Weert, 1997).

The NCTM advises teachers that it is their responsibility to teach and encourage students to use "calculators, computers and other technological devices" in the mathematics classroom (1991, p. 52). Taking a constructivist stance, the NCTM advises teachers that they must guide their students to select appropriate technological tools and to use tools deemed as appropriate by the classroom teacher for completing a specific task (1998, p. 43).

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[1] Phase in dates for the Western Canadian Protocol for mathematics began in 1996 and are to be fully implemented by 2001.

Technology Integration in Mathematics Instruction

In this section, I wish to examine issues that relate to the integration of technology in the mathematics classroom. I will explore how constructivistic tendencies relate to employing manipulatives in order to inform our understanding of how computer software might offer possibilities for improving mathematics instruction as an enabling rather than a "computer driven" form of activity. These challenges are points of entry for understanding the tensions that inform my research.

Broadly speaking, previously raised issues regarding a sound curriculum and the use of technology in the constructivist classroom can be viewed as a means of developing less narrow curricular objectives and opening up the possibilities for students to be co-creators of mathematical understandings. There is potential for greater understanding when students are moved from the task of rote memorization of facts and formulas, followed by their application, to "developing mathematics as a connected whole with an emphasis on conceptual understanding, multiple representations and their linkages to mathematical modeling and problem solving" (NCTM, 1989, p. v) when mathematics is enfolded in a cultural milieu. The use of technology can enhance the aspect of the cultural milieu in which students are expected to be able to access learning.

In background information published by the NCTM, the mandate for mathematics reform is articulated in the *Curriculum and Evaluation Standards for School Mathematics* (1989). The purpose of this document is to ensure that a common direction be established whereby the use of calculators and computers are an integral and enabling part of the definition of what it means to be mathematically literate in the world today (p. 1).

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[2] Due to public pressure, the new mathematics programs in high school will not be implemented with the speed originally anticipated.

Ultimately, the teacher must decide in which way to best implement the use of technology into the classroom. Howson and Kahane (1986) suggest that a teacher can opt to use the computer in the classroom in one of two ways. Firstly, the computer may be used for the purpose of presenting a lesson rather than using the conventional chalkboard or overhead projector. Secondly, the teacher may allow students to use that computer in order to foster interactions.

Feeling "the Math" in Mathematics: The *Hard* versus the *Soft(ware)* Touch?

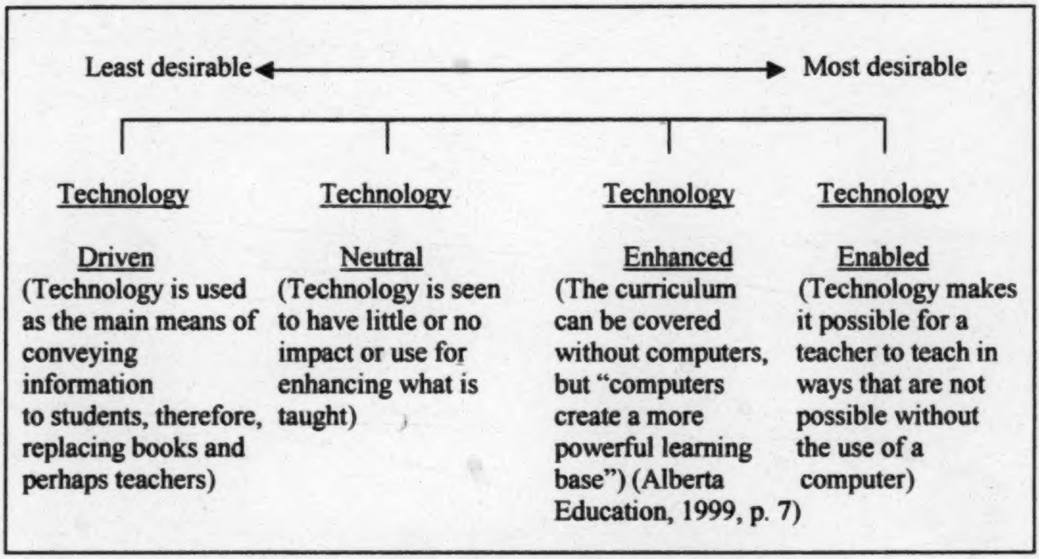
The use of manipulatives in the math classroom allows students to explore and create meaning in mathematics. Traditionally, the importance of the use of manipulatives has becomes less stressed in math instruction as students progress through to higher levels of mathematical understanding. The new mathematics curriculum in Alberta (WCP) argues that teachers should place greater importance on the use of manipulatives. At the secondary levels, graphing calculators and computers can be classified as math manipulatives as students can "manipulate" such things as spreadsheet data and graphs.

The integration of technology in school curricula is dependent upon teachers' views as to how useful a teaching tool such as the computer is used and how it fits into the curriculum (Alberta Education, 1999 p.7). In a draft copy of *The Professional Development for Teaching Technology Across the Curriculum: Best Practices for Alberta School Jurisdictions* (1999), four categories of curriculum "fit" are the following:

- technology neutral
- technology driven
- technology enhanced
- technology enabled (p. 7)

The four above categories serve as a framework that can be used by teachers to enable themselves to integrate technology into the existing curriculum. In other words, teachers are able to see where technology can be "fit" into the existing curriculum. What is hoped for is that teachers will fit technology integration into their classrooms in ways that are enhancing and enabling.[3]

If placed upon a continuum, I suggest that the placement would be as such:



Least desirable ↔ Most desirable

Technology Driven	Technology Neutral	Technology Enhanced	Technology Enabled
(Technology is used as the main means of conveying information to students, therefore, replacing books and perhaps teachers)	(Technology is seen to have little or no impact or use for enhancing what is taught)	(The curriculum can be covered without computers, but "computers create a more powerful learning base") (Alberta Education, 1999, p. 7)	(Technology makes it possible for a teacher to teach in ways that are not possible without the use of a computer)

Figure 1. Continuum depicting the four categories of curriculum fit.

What follows is a description of how a teacher might teach the same concept along the continuum of technology integration (Figure 1). The example I have chosen to use is one that describes investigating the doubling time for investments where $t=70/r$. In a technology driven classroom, the teacher might prepare this activity by setting up a table or a spreadsheet in which students enter the answer to $70/r$. The teacher enters different values for r into column one and enters a "logical function" into column three. The students then enter the answers for "time for investment to double" into column two. The computer would test the students' answers with the logical argument, and a message would inform the students if the answers were correct or not.

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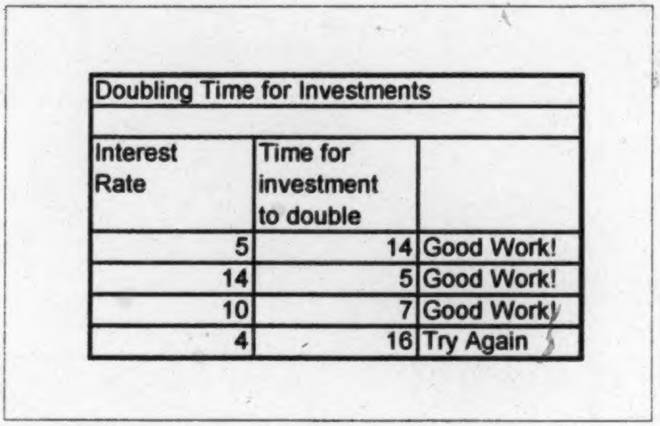
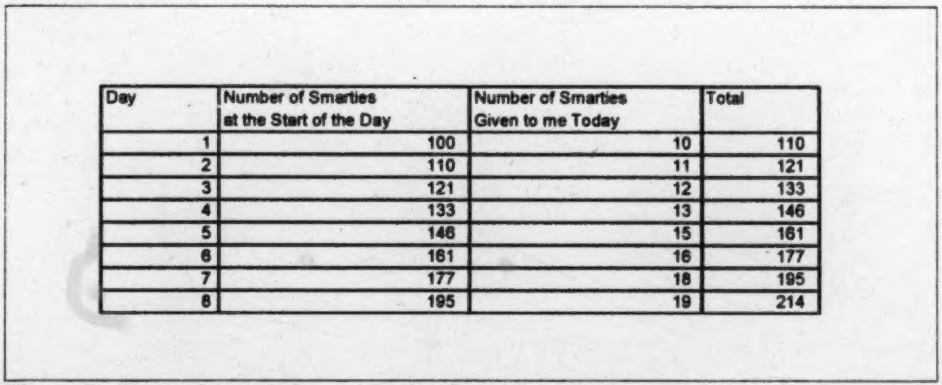
[3] Lakoff & Núñez (1997) use the terms enhancing and enabling to introduce their concept of metaphor. They describe "grounding" and "linking" metaphors as being respectively enhancing and enabling (one building upon the other). It is in much the same way that the continuum (Figure 1) is designed. Students must first be able to use technology as a source of enhancement before it can be used a source of enablement.



Doubling Time for Investments		
Interest Rate	Time for investment to double	
5	14	Good Work!
14	5	Good Work!
10	7	Good Work!
4	16	Try Again

Figure 2. Example worksheet – Technology driven classroom.

In a technology neutral classroom, students may be given a certain number of, for example, “Smarties” per day to represent the interest earned. Students would record the information (Figure 3) regarding how much their investment grew, and this information may then be stored in the form of a table they generated by using a computer. One day could represent a year; the number of days is recorded in column one. Students are given a number of “Smarties” that would represent an investment at a certain interest rate. Students are to record this number in column three. In order to keep a running tally of the number of “Smarties” they had received, students would record their total in column four and reference that amount to column two as a representation of the “opening balance.”



Day	Number of Smarties at the Start of the Day	Number of Smarties Given to me Today	Total
1	100	10	110
2	110	11	121
3	121	12	133
4	133	13	146
5	146	15	161
6	161	16	177
7	177	18	195
8	195	19	214

Figure 3. Example worksheet – Technology Neutral classroom.

Classrooms that are technology enhanced would have students create a spreadsheet and then enter text and formulas that calculate the doubling time for a given amount of money with a given interest rate, followed by changing the interest rate and investigating that scenario. From here, students are led to formulate their own conjectures as to 70/*r*. Finally, in a technology enabled classroom, the teacher might have the students access a fractal website where students can manipulate the data they enter, have the students describe what they observed, and then relate this information back to the doubling time for investments.

A constructivistic approach to instruction using technology in the classroom must be aligned to accommodate the use of technology as a tool in the classroom. As students in a mathematical classroom need to analyze problems, create representational models and make meaningful interpretations (Van Weert, 1997, p. 1:10), the teacher, when using a constructivistic approach, could move from teaching to the whole class as a group and relying on textbooks as the only resource to facilitating small group work which is student-centred in order to incorporate technology into instruction (Carl, 1995).

The introduction of technology in a classroom often has effects no one anticipates (Carl, 1995). For instance, the introduction of computers into the classroom complicates rather than simplifies teaching (Jensen and Williams, 1992). Hawkins and Sheingold (1986) add that computer use in the classroom affects curriculum, learning interactions, classroom management and the assessment and monitoring of student achievement (p. 41). On the other hand, Sierpinska's study indicated that teachers found the introduction of high powered graphics in teaching linear algebra to be beneficial because it afforded teachers more time to work one-on-one with students working through examples and discussing their thinking processes (1997, p. 24). What the researchers concluded is that rather than finding "the results," they found that teachers and students reacted to the technology in ways that did not conform to one particular theoretical framework or theory of learning. A pragmatic approach to thinking about technology integration lies in the schema I introduced in Chapter II – teachers move along a continuum from being driven by the technology to being enabled by it. My study argues that teachers should seek ways to enable students but that teachers should always be aware that the temptation to be technology driven may always be present for some.

The notion that technology enhanced learning in the classroom increases the propensity for uncertain outcomes to occur is exemplified in the *SkyMath* project (http://www.unidata.ucar.edu/staff/blynds/Skymath.html). *SkyMath* is a curriculum activity where students use real-time weather data to develop weather prognostications and self-evaluations of their weather forecasts. While the initial impetus of the project was focused on data collection and analysis, much of the learning that transpired was centred on student perceptions and assumptions about the predictive power of scientific knowledge. In addition to understanding how meteorology draws on mathematics and natural science, students also learn to appreciate the limits of human modeling and abstracting of the natural world. The *SkyMath* project suggests that, not only does technology integration enrich the possibilities for building new knowledge; it also enables students with the opportunity to reflect on the limits of human knowledge in a critical way they could not have without the computer activity. Constructivism is simultaneously about the composition and decomposition of knowledge and, as such, has particular poignancy for educators in a wide variety of projects, such as the *SkyMath* project, where technology enhancements have been used to facilitate learning (http://www.mirrors.org.sg/mathforum/mathed/constructivism.html).

An underlying goal of the teaching of mathematics is that students are able to create their own meaning out of new information as a result of assimilating new experiences to past experiences (Schoenfeld, 1987). At the same time, it is the underlying philosophies held by teachers, schools and school boards that influence the selection of software used for instruction. If teachers are challenged in their attempt to use constructivistic approaches in their classrooms, can the impact on such things as educational software then take longer to occur?

Many software packages that are available for instructional purposes foster rote learning rather than exploration (Solomon, 1986). Pre-packaged software tends to take a behaviouristic approach that drives instruction and is a form of pedagogy where someone other than the learner decides what should be presented and how (Solomon, 1986). According to Kieren (1997), drill and practice use of computers for teaching mathematics is viewed as one where the learner reacts to or acts upon information on the computer screen. The student's role becomes one of performing mathematical computations by "making an accurate representation of computer based mathematics in their heads and providing responses which could in some way be matched to pre-given standards" (Kieren, 1997, p. 2:3). Graphics and animation rarely transform software from drill and practice tools to exploration tools but act as a reward in order to encourage the learner to elicit correct responses (Jonassen, 1996, p. 5). This form of activity is "driven by the technology."

Some software packages promote discovery learning and heuristic learning (Solomon, 1986). These packages, I would argue, represent forms of enhancement. During the process of discovery learning, students are presented with topics from a real situation, and they are expected to find knowledge that already exists related to a given topic. Heuristic learning involves students using problem-solving techniques, within a given subject area with given tools, in order to create meaning and understanding. In other words, as Kieren suggests (1997), students are asked to do various forms of programming in order to "accomplish some mathematical task or to problem solve" (p. 2:3). Students use the computer to construct their own thinking and then are able to use the computer to see if what they constructed is practicable. Teachers help students find problem solving strategies, and it is the teacher who helps the child create analogical reasoning (Risku, 1996, p. 139).

Whatever the technical discussions may be concerning implementation strategies, constructivism is primarily concerned with the broader social implications of how computer enhanced learning impacts humans as relational learners (Risku, 1996). To this end, Winner (1993), in his critique of educational technology applications, outlined four potential pitfalls for educators who integrate technology into curricula, as detailed below:

> (1)Disregard for the social consequences of technical choice. (2) Exclusion of 'irrelevant' social groups. (3) Oversight of cultural issues and social origins of technical choice (in particular, rejection of the notion of 'autonomous technology'). (4) Lack of and apparent disdain for evaluative stances and repudiation of moral or political principles (p. 362-378).

These four shortcomings identify for teachers, in a succinct way, cautionary guidelines that attend to both the epistemological and moral aspersions that social constructivism brings to our understanding of what education is about. These potential problems can inform researcher-practitioners who attempt to integrate technology into the classroom in ways that are forms of enablement and enhancement rather than practices determined and driven by technology.

Changing Mathematics Instruction in the New Technologies

Goodlad, O'Toole and Tyler (1966) suggest that when technology is introduced, it should not be done in a step-by-step sequence in which the learner is brought from easier to harder tasks but, rather, in a "carefully considered approach" which involves consideration of the mental processes used by the learner. Teachers must also view the integration of technology as offering students tools that enhances or enables. It is in this way that the learner is able to access learning experiences that have long term intrinsic value.

As indicated earlier by Brooks and Brooks (1993), teachers must become learners with their students. Such an expectation, however, requires an appreciation of how educational change occurs. In schools, change is not always readily accepted because of the risks associated with uncertain and costly outcomes. Planning for change can alleviate the phenomenon of resistance to change. This is true of changes that, for example, occur in curriculum or in the use of technology as a teaching tool in mathematics. In order to implement technology successfully into existing mathematics programs, one must realize that "change takes time, change must involve all stakeholders, and problems and problem solving are part of the process" (Macmillan, Liu & Timmons, 1997, p. 223). From Bruner, one also needs to also reflect upon the fact that resistance to change is a fact of life "of the mind in culture"; indeed, for Bruner (1996), progress might be better conceived as "human beings overcoming received ideas" (p. 42).

Constant change is not the only reason why the implementation of technology has been resisted in the mathematics classroom. In the area of secondary mathematics, Gurney (1996) suggests three reasons for the lack of computer-mediated instruction. Firstly, there is an unavailability of technological software related to the mathematics curriculum. Secondly, there are insufficient numbers of computers available to students for CBI to be implemented. Thirdly, there is a lack of expertise on the part of teachers to effectively use computers as a teaching tool in the area of mathematics.

Consistent with the continuum I introduced at the onset, there are a number of conflicting views regarding when and how the integration of technology is best incorporated in the mathematics curriculum. M. Hill (1993) cites many math professionals' views concerning at what grade level different types of technology should be introduced. One professional in the study, Steen, executive director of the Mathematical Science Education Board, states that computers are not essential for use in classrooms below the second year of college. Steen (as cited in Hill, 1995, p. 2) professes that the use of computers before that time is "helpful, but not essential" (p. 24). Another member of Hill's study, Schwartz, who is a professor of mathematics and physics at Harvard and M.I.T. and the creator of *Geometric Supposer*, views computers as a necessary tool in the instruction of mathematics at any grade level. Schwartz and Yerushalmy (1987) regard computers as flexible tools that can support and expand learning. With a lack of direction for the use of the computer in the classroom, it seems that Schwartz and Yerushalmy's tenet is that the computer will allow students to create their own learning. I sense that Schwartz and Yerushalmy advocate that students have a natural propensity to use the computer without any intervention from the teacher. Finally, software developer Bardige (as cited in Hill, 1995, p. 2) declares, that if a first grade student is given a calculator, he/she is going to be immediately as good at doing computations as the best person in history ever was. When the views of the above noted researchers are juxtaposed against one another, a common element of all constructivistic approaches in education emerges: in the mind of the learner, meaning making is a dynamic seesaw exchange between stability and disruption.

Boudourides (1998) argues that we need to understand technology not as a "good" or a "bad" presence in the classroom but, rather, as a cultural force that gives students tremendous new opportunities for "interpretive flexibility" (p. 9). Clearly, Boudourides is leaning toward an orientation that sees computers potentially as a form of enhancement and enablement. Instead of the interminable debates about whether or not technology ought to be introduced into the classroom, Boudourides would have teachers simultaneously engage in and critique computer applications in their classrooms in ways that constructivism understands all social phenomena. As with any other aspect of social change, constructivism reminds us that the introduction of technology into the classroom will be not unlike any learning – a living in between stability and disruption.

A further complication within the myriad of views regarding technology integration has been the literature on gender and learning. While gender has been found to be a factor in student results, according to Gurney (1996), other important factors such as attitudes, feelings of self-efficacy and the types of software used may play a role as well. Harding (1997) suggests that, not only do peer groups play a major role in gender differences, but also "the skills, identities and self-perceptions" teachers possess are part of the influencing factors (p. 20).

With the number of positions and ways of "thinking about thinking" taken by leaders in the field of mathematics, is it any wonder that teachers are equally confused by the process of change and the use of technology in the classroom? Internalized models of learning will have a profound impact on how technology is viewed in the teaching-learning process. The use of computers in the teaching of mathematics is extremely important because they can provide a variety of unique learning experiences that allow students to become actively involved in their own learning.

Finally, what are the shifts that will take place in the culture of mathematics teaching amidst the new technologies? First and foremost, teachers must assess their philosophy of technology and pinpoint their underlying assumptions about technology (Flower, 1998). It is in this way that teachers can lay down a path (and not be "driven") for which way they envision the implementation of technology in their classrooms. As a caution, teachers must become familiar with different approaches (Figure 1) used in order to infuse the use of technology within the classroom setting.

Before teachers can adequately address the needs of their students by using technology, they should possess necessary computer skills in order to guide students through their learning. Is it necessarily the case that teachers need to be experts in the area of computer use in order to help students learn and can use the opportunity of the situation to learn together with the students? A knowledge base, however, allows for teachers to enhance the teaching of mathematics because there is a purpose for using computers as a teaching tool. Dubinsky and Tall (1991) believe that it is not enough to simply add the use of computers to the curriculum; there must be specific aims kept in mind by the teacher, or meaningful learning in mathematics does not occur.

"Minding" the Student: Constructivism and Computers in the Mathematics Classroom

This review has identified the pedagogical issues surrounding philosophical conceptions of "other minds" and the practical challenges teachers face in integrating technology into learning activities that recognize mathematics as an opportunity for students to make their way in the world. The issues teachers face are complex and require careful rethinking not only of our embedded assumptions about what is cognition, but of the role of the teacher in an electronic culture that increasingly challenges our sense of coherence. In this review, I have argued that the challenges range from the nettlesome problems of "what is mind" to the banal realization that some current software is extremely limited in its potential for mathematics instruction (Leron & Hazzan, 1997, p. 19:3).

What is subsumed in my research is the imperative that teachers who use a constructivist approach ought to recognize that students make their way in a world that is dynamic – that mathematics is neither a canon nor a relativistic body of subjective knowledge. Mathematics instruction is informed by the cultural limits that inscribe all human artifice: that as teachers we hope to refine, like our students, our mathematical constructions that can "withstand all tests" (Leron & Hazzan, 1997, p. 19:3). Such hope may be just an empty dream, but it is a worthwhile starting point for engaging the possibilities of integrating computer technologies into the mathematics classroom.

The Effect of Affect in Mathematics Learning

Hixson (1993) argues "we all are guided, in several arenas of our lives, by attitudinal infrastructures and frameworks of belief that reflect reality or truth as we have come to know it" (p. 48). According to Bandura (1986), individuals possess the ability to control their feelings, actions, motivation and thoughts. It is through this "self system" that individuals are able to perceive, regulate and alter their behaviors. Through interpretations of performance, people alter their environments and their self-beliefs. The alterations an individual makes then inform and alter subsequent performances undertaken by the learner. Attitudes are seen as being negative or positive. One need not look far to find examples of negative attitudes towards mathematics. It is not uncommon to find adults who view mathematics as one of the hardest subjects they encountered in grade school. Mathematicians have typically been viewed as people who work in seclusion and are introverted, having little to no social skills (Jennings & Dunne, 1996).

The analysis of attitude and learning is not new to the area of mathematics. During the 1960's and 1970's many Likert-type instruments were designed to assess the attitudes of students towards mathematics regarding affective variables that might effect student performance in mathematics (Fennema & Sherman, 1976; Holly, Purl, Dawson & Michael, 1993; Mclure, 1971; Sandman, 1974; Suinn, Edie, Nicholletti & Spinelli, 1972). Among other things, these tests were designed to measure anxiety that students felt towards mathematics, the relationship between attitudes towards mathematics and achievement, gender differences and attitudes, and how teachers' attitudes influenced students' attitudes towards mathematics (Aikens, 1979). Perhaps the most influential of all attitudinal tests has been the *Fennema-Sherman Scales* with its contribution to the research on gender-related differences as well as general attitudes towards mathematics (McLeod, 1994).

Research that was once "heavily influenced by the theories and methods of cognitive science…revealed in a new way the importance of student beliefs about mathematics" (McLeod, 1994, p. 641). In the past ten years, Schoenfeld (1989) has put forth a vast amount of research that indicates how a student's beliefs about mathematics influences their problem-solving performance. Schoenfeld found that successful solution of mathematics problems depends upon a combination of resources, heuristics, control processes and beliefs, all of which must be learned and taught.

More recently, researchers have used the result of previous research as a clear indicator that the affective domain should include researching the effects of self-concept upon performance in mathematics (Nicholls, Cobb, Wood, Yackel, & Patashnick, 1990). McLeod (1988) viewed the key role of research in mathematics to be shifting to one that takes into account students' emotional reactions to solving non-standard problems. It is

McLeod's view that positive and negative reactions are given equal recognition as to how they impact upon students' mathematical cognition but he cautions that there is still a large void that exists between affective issues and the enhancement of classroom practice in the field of education (McLeod, 1994).

With recent shifts towards a constructivistic orientation in the NCTM standards and in Alberta Education's *The Common Curriculum Framework for K-12 Mathematics: Western Canadian Protocol for Collaboration in Basic Education*, students are being asked to solve higher order problems that are related to a more "real-life" context. Research has indicated that, while the aim of more complex problems for problem solving are designed to motivate the learner's interest in mathematics, the contrary is often the result (Becker, 1983). According to McLeod (1994), there still remains a vast amount of research that needs to be completed regarding issues that lie beyond gender-related differences; the research that has been completed in this area surpasses "our understanding of differences in achievement" (p. 642), therefore emphasizing cognition over motivation.

Attitudes towards Mathematics, Computers and Constructivism

The simple greatest challenge facing mathematics teachers who draw on constructivism in their classroom practice is the recovery of meaning and purpose that is linked to the broader cultures of students. As Jennings and Dunne (1996) argue, mathematics can no longer be regarded as a place set apart where "truth and social order do not coincide" (p. 3). As children are moved from rapt attentiveness of elementary school where play and creative story-telling is used to motivate students, we see, as Jennings and Dunne (1996) argue, the arrival of the high school student experience where seatwork and routinized drill predominates.

Attitudes about doing mathematics – the way we feel about doing mathematical activity – must be central to our understanding of constructivism. Mathematics in the classroom must reflect the ways we need to think about our world. As Bruner (1971) argued early on, the willingness to learn *must be found within the exercise*. "If the tasks are silly in the sense of being meaningless, arbitrary, and without visible means of checking progress, the drive to completion is not stimulated" (Bruner, 1971, p. 63). Bruner paints a poignant picture. If students are called upon to endlessly wander through a maze of meaningless questions and puzzles, with no real end point in sight, can the lack of motivation and sense of alienation surprise us?

Thus, self-efficacy becomes central to student attitudes. While the impact of self-efficacy and the acquisition of computer skills has not been thoroughly researched, Miura (1987) suggests that self-efficacy may be an important factor in the learning of computer skills. Bandura (1982) agrees that positive self-efficacy may encourage people to learn new skills, whereas negative self-efficacy may hamper individuals from learning new skills although Bandura does not tailor his views only to the acquisition of computer skills. Bandura (1977) regards positive self-efficacy as manifesting itself in individuals who are more actively engaged for longer periods of time. These individuals are more persistent in their efforts as well.

Teaching actions should offer students opportunities to possess "a beginning, a plan, and a learning." (Bruner, 1971, p. 63). Over twenty years later, Bruner reframed the organic basis for learning around a more culturalist stance, arguing that we all possess "cultures in mind" as we mature and grow and that the need for "beginnings" and "ends" is common to all cultures. Rather than getting mixed in a nature versus nature debate, all we need to draw from Bruner is the culturalist sense that there is a persistent pattern in human culture: to find agency and possibility in beginnings and endings. Without over-determining Bruner's culturalist schema of the journey and the journeying, certainly mathematics teachers should be compelled by the notion that learning is inextricably bound-up in the human need to find purpose. In other words, learning is connected, as Bruner (1971) framed, to the need for us to locate the willingness to learn "within the exercise" (p. 66).

Using Bruner's notion of a beginning, a plan and a learning, Woodrow (1991) suggests that, because students' attitudes towards computers are such a crucial issue, it is necessary to continually monitor students' attitudes if computers are to be used as a teaching tool. Hill, Smith and Mann (1987) found that students' attitudes towards computers seemed to be significant predictors of self-efficacy in word-processing, e-mail and CD-ROMs. Although I was unable to find literature that linked attitudes, self-efficacy, mathematics and computers, Glass (1984) reported that using a computer to teach mathematics can enhance interest in mathematics for both men and women. Related to computer usage in the mathematics classroom, Ganguli (1992) reported that the use of computers for teaching mathematics did indeed "favorably influence students' attitudes" (p. 615) due to the computer-generated graphics and experimentation that lead to an increase in student discussion.

III. METHODOLOGY

Introduction

It is through this study that I investigated how a particular technology based unit of instruction might affect students' attitudes and feelings of self-efficacy towards mathematics and computer usage in the classroom, the focal point being the identification of shifts in students' attitudes and possible reasons for this shift. Additionally, this research undertook the purpose of identifying which activities in the unit of instruction the students enjoyed the most as well as investigating ways in which the activities made the learning of mathematics easier or harder for the students.

Twenty-three students enrolled in a junior high school in rural central Alberta participated in this study. All participants were from grade eight, and all participants partook fully in the study. Students' self reports and perceptions of their engagement with the computer activities formed the basis for my study. The classroom teacher and myself analyzed student comments against our observations of student engagement during the computer activities. In terms of assessing changes in student attitudes, this study draws on four data sets: changes noted in the *Fennema-Sherman Scales*; student self reports; classroom teacher reflections; and, lastly, my observations.

The *Fennema-Sherman Scales* were used as a means of selecting participants for the follow-up interviews. It was also from the *Fennema-Sherman Scales* that interview questions emerged as opposed to my formulating the interview questions beforehand. Having completed an initial analysis of that data, I had a better sense as to what changes in attitude, if any, were indicated. Demographic information, including such data as age, gender, and computer access at home, were also collected (Appendix B) for use in attempting to analyzing possible relationships to attitudinal changes.

Methodology and Rationale

This study used, for the most part, methodology associated with carrying out case studies. The major point of departure of the research methodology used from case studies was the incorporation of an attitudinal survey instrument, the *Fennema-Sherman Scales.* Students completed two spreadsheet activities, one database activity and one PowerPoint activity. All of these activities involved students in completing mathematical activities using cultural artifact that resonates Bruner's (1996) sense of getting "unstuck." The activities were designed to have students use the Internet to collect data followed by activities which were designed to enable students to classify, sort and analyze that data. A brief summary of these activities follows.

The two spreadsheet activities were designed to allow students the opportunity to create spreadsheets for the purposes of calculating exchange rates between Canadian currency and the currencies of five countries of the student's choice. In order to complete this activity, students were to access a foreign currency exchange website where they could locate the information required to complete calculations for any given sum of Canadian funds to the foreign currency being investigated. With the use of a division formula, students used the spreadsheet to complete the conversion. The second spreadsheet activity was an extension of the first. Students were required to use the exchange rates from the first spreadsheet in order to calculate the price of purchasing souvenirs in foreign countries. The students were required to hyperlink into online catalogues from five countries of their choice; the catalogues quoted the cost of goods in the denominations of the country of origin. In the spreadsheets, students entered the cost of the goods and then calculated the cost of the goods in Canadian funds. Students investigated the cost of the goods selected in Canada and then calculated the difference between purchasing the goods in Canada and in other countries. This information could then be used for students to create a graph in order to have a visual representation of the differences in the cost of goods between various countries and Canada.

The database activity involved students classifying, organizing and sorting data. For the five countries selected for the spreadsheet activities, students entered data already collected as well as additional information such as the percentage of difference in the cost of goods, whether a visa is required to travel to the countries, and two interesting places to visit including the cost of admission, if any. (This information is currently stored so that, in following years, students will be able to compare changes in exchange rates and costs of living.)

The final activity consisted of a multimedia presentation in which students were allotted the sum of $5 000 and planned a complete itinerary, including all travel costs, for visiting two different cities in two different countries; students made critical personal choices in developing their travel itineraries. Once students decided upon two countries and cities to visit, I searched for sites that would assist them in gathering information in order to limit the amount of time students spent searching on the Internet. Given a limited budget, students were required to make informed choices about their travel plans and personal priorities while traveling. The activities the students completed drew upon a broad spectrum of their cultural backgrounds and experiences. The culminating activity of a multimedia presentation served as a means to allow students to synthesize and analyze information contained in the spreadsheets and databases.

The data collection consisted of several steps. Firstly, I created the activities that were used in the unit of instruction. During this conception stage, I familiarized myself with literature pertinent to this study as well as deciding which *Fennema-Sherman Scales* I thought would be most useful to me for this study. Following the finding of a research site, an ethics proposal was made and accepted. Students' attitudes towards mathematics were then measured using sections of the *Fennema-Sherman Scales* (Appendix C). The students' attitudes were measured before they were exposed to the spreadsheet, database activities and a multimedia activity. Upon completion of these activities the *Fennema-Sherman Scales* were re-administered with the goal of identifying any changes in students' attitudes. The intent of using the *Fennema-Sherman Scales* was not to measure quantitative shifts in attitudes but, rather, to identify potential focus questions for interviewing the students about what they saw as sources of engagement for themselves. The focus questions used for the interviewing stage emerged from the survey questions. Students were invited to reflect upon their pre- and post-attitudinal test and to comment upon why they answered differently. Students were also asked to comment on which activity they enjoyed the most and if and how mathematics was made easier or harder through the use of the computer.

At the onset of the study, two teachers who taught the same class different subjects had agreed to participate in the study. Since one of the teachers, the lead teacher, was an administrator in the school, he was able to remain with the class during all research sessions. The supervising teacher, who was the students' science teacher, agreed to allow the students to participate in the study during her science class time. After the first day of the study, science teacher decided to act as a support teacher while fulfilling the role of assisting students when they were unable to proceed with the activities. The reason for the change was the teacher's timetable commitment. She taught another class during the first of the two periods that the research took place and teacher felt unprepared to enter into a leadership role when the students had already been working for thirty-eight minutes. The lead teacher was responsible for the majority of the teaching, and I acted as a reseacher-teacher. When the classroom teacher was unable to adequately cover the lesson objectives, we used a team teaching approach to best teach the activities.

While students were involved with the activities, they were asked to reflect upon what they were doing and how they felt about what they were doing. The students' responses were collected in the form of journal entries that had been collected through e-mail discussions between the students and myself. After a student in the school sent death threats to fellow schoolmates, the e-mail accounts of all students were removed, and students recorded their impressions as journal responses. Additionally, I periodically videotaped students during the sessions and asked them, at that time, to reflect orally upon their experiences. All students were interviewed as a final information gathering strategy following the re-administration of the *Fennema-Sherman Scales*.

To further inform my observations, the lead teacher involved with the study was asked to reflect upon the class immediately following each day's session. During the course of the post-session interviews, I asked the teacher involved to clarify or expand his thoughts in order to more fully understand his perceptions. All of these sessions were audiotaped.

Case Study Research

There has been considerable controversy regarding the use of qualitative and quantitative data collection methods in case study research. Combining the two methods has become a more acceptable practice (Kidder and Fine, 1987; Merriam, 1988; Miles and Huberman, 1984), but it is not done without much debate. Kidder and Fine (1987) advocate combining the two research methods as triangulation, and validity and reliability of the study are enhanced as a result.

My case study research draws upon the work of Guba, Lincoln, and Merriam. For Guba and Lincoln (1981), a case study approach is one where the researcher ascertains the viewpoints of the participants by using a number of sources in order to elicit data and then proceeds to refine the study's parameters. Merriam (1988) argues that case study research "is an ideal design for understanding and interpreting observations of educational phenomena" (p. 2). Importantly, case study refers to the collection and presentation of detailed information about a particular participant or small group and frequently includes accounts of subjects themselves. From the data collected, the researcher is able to draw conclusions only about that participant or group and only in that specific context as "we do not study a case primarily to understand other cases" (Stake, 1995, p. 4). Researchers do not focus on the discovery of a universal, generalizable truth, nor do they typically look for cause-effect relationships; instead, emphasis is placed on exploration and description (Janesick, 1994; Stake. 1994). Case studies are not designed to test theory but, rather, might be used to construct theory (Merriam, 1988).

This study deals with identifying possible changes of students' attitudes and feelings of self-efficacy towards mathematics in the context of a specific learning activity. The study concentrated on the activities' potential ability for changing students' attitudes and feelings of self-efficacy towards mathematics while using the computer applications. Of practical interest in this study are students' self-reports of perceived changes in attitudes, or the lack thereof, after being exposed to computer-mediated mathematics activities.

Illustrative Case Studies

My study limits itself to illustrative case studies that are primarily one or many descriptive studies. They typically utilize one or two instances to show what a situation is like which, in turn, helps the researcher interpret data (Davey, 1991). As is true with other types of case studies, illustrative case studies serve primarily to make the unfamiliar familiar and to give readers a common language about the topic in question. As with many other types of case studies, illustrative case studies caution that the researcher should limit the number of cases studied. It is my aim to use four parts of the *Fennema-Sherman Scales* and one adapted version of the aforementioned scales in order to select students for further interviewing after completion of the computer-assisted mathematics activities to inform my "case" (the unit of instruction as lived). Students were questioned regarding their perceptions as to why they did or did not demonstrate a change in attitudes towards mathematics given the instructional sequence used.

Research Design: The "Pedagogy of the Question"

Using a research design in which the "pedagogy of the question" rather than the "pedagogy of the answer" guides how research will occur places the decision of transferability on the reader and not the researcher (Bruss & Macedo, 1985). The participating teacher provided member checks by reviewing quoted information and making sure it accurately represented his views (Merriam, 1988). The reader has his or her own views and contexts that intersect with the limitations and conditions of the analysis that I am presenting. According to Bruss and Macedo (1985),

> Unlike the pedagogy of the answer, which reduces learners to mere receptacles for prepackaged knowledge, the pedagogy of the question gives learners, the "language of possibility" to challenge the very constraints which relegate them to mere objects (p. 8).

The pedagogical content, that is to say the "relevance" of my study, emerges between the shared meanings that I present and the questions the reader brings to the text. I see this as the critical moment of enablement in my research. This underlying assumption parallels that of Stake (1995), who believes that it is the researcher's responsibility to assist the reader in making high-quality understandings by bringing forth relevances.

A second purpose of this study is to aid the reader in making linkages of my research to his or her experiences. These linkages can be made in three ways. Firstly, from one where scientifically obtained knowledge is viewed as superior to one where intuitively derived knowledge is regarded as an equal opportunity. Secondly, from a cause and effect view of knowledge to one that considers knowledge as being situational. Thirdly, from a view that assumes to have answers to "complex social questions" to one in which problem solving and negotiation of solutions are important outcomes of research (Smyth, 1989, p. 7). In this study, I anticipated that I would, and did indeed, rely upon all three linkages equally.

Role of the Researcher

From the onset of this study, I acted in a variety of roles. Prior to commencing the implementation of the activity, I created the unit of instruction. I then trained the teacher involved with this study to use the various spreadsheets, database and multimedia presentation applications required. Once in the classroom, I took the role of researcher-teacher and of data collector. I assisted the teacher as was required at any time during the lesson presentation. I circulated throughout the classroom in order to assure that students understood what was being asked of them insofar as completing activities was concerned. Finally, I developed the interview questions for collecting data as well as analyzed the data.

Data Collection

Data was collected using the *Fennema-Sherman Scales* that was administered pre- and post-exposure to the learning unit. A survey of demographics was also used to build the context of the students' experiences that they brought to the activities. Students were audiotaped and videotaped while they were engaged in the activities involving mathematics and computers. All students were asked to comment in a journal that they submitted to me via e-mail or on paper. In turn, I responded to the student responses in an attempt to elicit further information regarding their views towards mathematics and computers. Following each session, the teacher was asked to share his views with me as a form of reflection; these conversations were audiotaped. I also maintained a personal reflection journal during the course of the research period.

The study took place over a two-month period and was not always carried out on a weekly basis due to school holidays and field trips. Appendix F details the research schedule. During the first two visits, student progress was recorded using one video camera with an attached microphone. One tape recorder was also placed at the opposite end of the classroom from the video camera and I carried one hand held recorder to record student/researcher interactions. The video camera was intended as a means of recording individual students' responses to questions posed by other students, the classroom teachers and myself. After the first two days of data collection, I decided not to use the videotape as a means of recording classroom interactions as there was no information being recorded that I found useful to the research. As the recorder was stationary in a corner of the classroom, it became too difficult to transcribe what the students were saying as a large portion of the audiotape was muffled due to the lack of proximity of the video camera to the students. Instead, I used the handheld tape recorder to record students' dialogues.

Interviews

Interviews formed the primary source of the data collected used in this study. It is through the process of interviewing that students' and teachers' stories can emerge in relation to their experience and how they think about their lives (Bogdan & Biklen, 1992). The role of the interviews allows the researcher to view "the subjects" as "human beings" (Fontana & Frey, 1994).

Informal Student Interview

On a daily basis during the course of the study, all students were asked to reflect upon the mathematics with which they were engaged. They were asked to comment on the activities in general, what aspects they found frustrating, what did they like/dislike about a given activity, which activity did they like the most/the least, what they had accomplished, what mathematics they were doing in each activity, and how they coped with "getting stuck." The students' responses were either videotaped or audiotaped. During this aspect of the study, I focused on observing and noting interactions between the teacher and the students, interactions between the students themselves and interactions between individual students and the computers.

Formal Student Interviews

The questions used during the final student interview emerged as data was collected over the course of the learning experience and as the initial and follow-up *Fennema-Sherman Scales* were interpreted. All students were interviewed five days following completion of the unit of instruction when students were interviewed with their partners for the final multimedia presentation. Specifically, students were asked to elaborate on the following: what mathematics they were doing while using the spreadsheets; how the mathematics was made easier because of the technology; how the mathematics was made harder because of the technology; what they liked the most about using the computer to do mathematics; and what they liked the least about using the computer to do mathematics. During the final interviews, students were asked to elaborate upon comments they had previously given in class and observations made by myself and the teacher as well as to account for changes or the lack of changes as to the *Fennema-Sherman Scales*.

Teacher Interviews

Interviews with the teacher involved in this study followed each day's sessions. I, therefore, asked the teacher involved with this study to share perceptions of the activities with me as well as any insights that possibly accounted for changes in individual students' attitudes toward mathematics and their feelings of self-efficacy. The interviews took the place of a journal entry and were informal in nature; that is to say, no formal questions were asked. The teacher was given the opportunity to reflect upon what he had been and to comment as to reasons why he thought these occurrences had transpired. On occasion, I asked questions, but the questions were to clarify points that were made by the teacher.

Survey Instrument

In order to analyze changes in students' attitudes towards mathematics, the *Fennema-Sherman Scales* was administered to the students before they commenced the mathematics and computer activities and again once the activities were completed. From this instrument, the following scales were selected: the Confidence in Learning

Mathematics Scale, the Teacher Scale, the Usefulness of Mathematics Scale and the Effectance Motivation in Mathematics Scale because I concentrated my study on changes in attitudes and feelings of self-efficacy related to these areas. I adapted the Confidence in Learning Mathematics to include computers and, thus, named it the Confidence in Learning Mathematics with Computers Scale (Appendix C).

Each scale was designed to measure attitudes a person holds regarding mathematics. The *Confidence in Learning Mathematics Scale* is designed to "measure confidence in one's ability to learn and perform well on mathematics tasks" (Fennema & Sherman, 1976, p. 324). The *Teacher Scale* is intended to "measure students' perceptions of their teachers' attitudes toward them as learners of mathematics" (Fennema & Sherman, 1976, p. 324). The purpose of the *Usefulness of Mathematics Scale* is to "measure students' beliefs about the usefulness of mathematics currently and in relationship to their future education, vocation, or other activities (Fennema & Sherman, 1976, p. 325). The aim of the *Effectance Motivation in Mathematics Scale* is to "measure effectance as applied to mathematics" (Fennema & Sherman, 1976, p. 325). In an attempt to assess students' attitudes towards the use of computers for the teaching of mathematics, the final referent was included.

Documents: Response Journal and Others

I was unable to take field notes in class as a means of allowing me to comment on issues that I saw arising from my data collection and daily observations as I was too busy as a researcher-teacher to keep accurate field notes. Instead, immediately following the sessions, I wrote my reflections down in a response journal. This was done prior to recording the teacher's reflections so that his views and reflections would not influence what I had observed and noted. Student documents such as homework or completed assignments directly relating to the computer activities were collected to assist me with interpreting other forms of data collected.

Data Analysis

Interviews: Informal, Formal and Teacher

All audiotapes and videotapes from the formal and informal interviews, classroom observations and audiotaped discussions were transcribed verbatim as soon as possible after collecting the data (Glesne and Peshkin, 1992). All transcripts were used for triangulation of observations made in this study. For the purpose of this case study research, I opted to use a reflective analysis, which, according to Tesch (1990), is a process that involves the researcher's use of intuition and judgement in order to represent or assess the events that have taken place during the collection of data. The process of reflective analysis involves "introspective contemplation, tacit knowledge, imagination and artistic sensitivity" (p. 69). All transcripts were examined and re-examined in what Gall, Borg and Gall (1996) describe as from a hermeneutical perspective (p. 571). Reflective analysis is a term that describes a broad range of reflexive exchanges between and among researchers and their subjects. A hermeneutical perspective is a more specific strategy – one that focuses on the multiple meanings of text and speech acts. For example, a reflective practitioner may draw upon a variety of strategies in order to identify conflicting meanings and human subjects. Hermeneutical perspectives focus specifically on the layered meanings which human subjects bring to interpretation.

In order to analyze the data, experiences and observations were summarized in tables (Miles & Huberman, 1994). An example (Appendix F) of such a table was titled: "What I liked most about doing math on a computer." Following the title were columns indicating the activity, the name of the student, the behaviors demonstrated by the student and the comments made by the student.

Survey Instrument

In order to interpret the data collected from the *Fennema-Sherman Scales*, a frequency of responses per statement chart was created. A *z*-score analysis was used in order to establish a common scale to calculate differences in the mean from the pre-test to the post-test. The *z*-scores were calculated using a 0.5 confidence level.

Z-scores indicate how far, and in what direction, an item deviates from its distribution's mean. The *z*-score is expressed in units of its distribution's standard deviation (http://www.animatedsoftware.com/statglos/sgzscore.htm) ranging from negative three (–3.00) to positive three (+3.00). The larger the absolute value of the z-score, the farther the score is away from the mean.

Document Analysis

Samples of all of the students' work and written reflections were collected in order to help track changes and substantiate findings that emerged from the interviews, the *Fennema-Sherman Scales*, and from observed changes in the classroom setting. Merriam (1988) views the use of such documents as an essential part of data analysis and believes that they can be used in the same way as interviews for the purpose of providing a richer description and possibly creating new categories. For the purpose of this study, the students work was used as a means of relating the amount of work completed by students with their attitudes and their feelings of self-efficacy.

Ethical Considerations

I secured all necessary University of Alberta approval for the research study. Parents of the students in the grade eight classroom provided written consent to allow their children to participate in the study before the students were allowed to participate. Students and their teacher agreed to participate by signing a letter of consent. Participants were asked to volunteer to participate in the interview process. Although all people involved in the study had the opportunity to discontinue the research at any time for whatever reasons they deemed appropriate, no one opted to do so. The identity of all participants was protected, and pseudonyms are used in the report to protect confidentiality.

Methodological Assumptions

The qualitative research design in this study, informed by the "pedagogy of the question" (Bruce and Macedo, 1985), assumes that "there are multiple realities - that the world is not an objective thing out there but a function of personal interaction and perception" (Merriam, 1988, p.17). These realities are not stagnant; they change over time and are reflected in classrooms as they, too, are dynamic in nature. A qualitative design is, therefore, an effective research design to use in educational settings (Gay, 1997). Because of the dynamic nature of education and peoples' realities, students' attitudes and their feelings of self-efficacy are, thus, equally liable to change.

Regarding mathematics education research, McLeod (1994) argues that methodological practices that rely on qualitative approaches represent an important step in identifying how affect influences mathematical learning. Even with these advances, McLeod (1994) cautions that "the research community is still struggling to build a suitable framework for the study of beliefs and attitudes related to mathematical learning" (p. 643). Central to this research project is the assumption that student attitudes and efficacy are key factors in developing mathematical learning.

Specifically regarding illustrative case studies in general, weaknesses include the requirement of presentation of in-depth information on each illustration. Due to the time constraints, there may not be enough time for on-site, in-depth examination. The most serious problem involved the selection of critical instances; "the case must adequately represent the situation or program. Where significant diversity exists, it may not be possible to select a typical site" (Davey, 1991). As the reseacher-teacher, I was involved in and not removed from the research process in a qualitative design.

In closing, I am reminded that my thesis ought to reflect the multiple voices and experiences of the students and teachers involved in the study. I will remain mindful of the fact that the process of documenting the study is always entangled by the limitations and possibilities of my observational and critical skills. I will remain implicated in this sense as part of the study as both a biased observer and a committed researcher.

IV. THE RESEARCH STORY

Overview

Chapter IV introduces the people involved in this study as well as presents some background life stories of these people. Pseudonyms have been used rather than using the individuals' actual names. The classroom's and school's context are also discussed as they play an integral part of the learning environment. Following this description is a presentation of the research data for each of the activities in which the students were engaged. The section is introduced in chronological order (see Appendix F for a timeline of the study). Finally, some of the implications and questions that arose during the research phase are discussed.

Introduction

Technology, such as computers, is playing an ever-increasing role in our classrooms. It is my view that the impact of technology in the classroom is one that will be studied for years to come. Just as in previous decades, with the advances of technology in the film industry, for example dubbing, and in calculators, to name two, new advances in technology will enable teachers to enhance their presentation of daily lessons. Computers have the potential to enable students to explore the curriculum in "real time" applications rather than text based prescriptive fashion. Teachers need to tap into the possibilities of the use of technology in ways that are comfortable to them and find manners in which technology fits the curriculum in ways that the teachers see fit.

This study examines the impact of computer and web-based activities on the attitudes and efficacy of students towards mathematics. Activities that were used in this study were developed by myself as a means of connecting computer and web based activities to the existing Alberta mathematics curriculum. Within the context of the activities, the following research questions arise: Is there potential for computer activities to change the attitudes and the feelings of self-efficacy of students towards mathematics? What attitudes showed the greatest change during the course of this study?

Instructional Sequence: Possibilities for a Technology Enabled Curriculum

‘Acting Out’ Constructivism: An Enactivist Beginning

When creating the technology based unit of instruction used in this study, I attempted to create one that was constructivistic in its approach. Constructivism, as Davis (1995) writes, “has been used (as) an umbrella term for a range of loosely related notions” (p. 53). Davis argues that “it has been subject to a variety of interpretations” (p. 53) and, therefore, the meaning of the term is highly problematic. It is in this light that I, too, have chosen to limit my use of the term to the general movement rather than to the various perspectives that are associated with constructivism.

The constructivist orientation is one that believes that students must build knowledge through a series of personal associations and acting through learning occasions in order to formulate ideas (Vermeulen, Volman & Terwel, 1997, p. 19). This definition is expanded by Ritchie and Baylor, who state that there are two common characteristics of the constructivist environment: “…students learn by actively constructing, rather than acquiring knowledge and that the purpose of instruction is to support this construction rather than the communication of information” (1997, p. 27). These points reinforce what I offered earlier as a distinction between realism and constructivism. Constructivistic learning environments attend to the different ways students engage the objects of the world. It is the role of the teacher to find more than one way to teach mathematics. As Davis (1995) asks, “What are we that we might know mathematics?” (p. 39).

It is from within Davis’ question that I reflect back to a moment from my year of teaching kindergarten when I saw a student’s “way of being” breaking through the realist context of my own teaching. While watching a film on Australia where a platypus was swimming through the water, a student asked me, “What is that weird thing? It looks like a beaver-duck.” I realize now that it was my own investment in a fixed Cartesian view of the world that did not allow me to see the tremendous mental capacity that was brought forward in that student’s question. Indeed, a platypus does have the appearance of a beaver and a duck. It does live as a species, somewhere in between a strict categorization, by being both mammal and reptile.

I now realize many of the limitations of my own assumptions about learning. I have become committed to develop learning opportunities for students that recognize the process of learning as "dialogical." As Davis (1995) posits, there is not one single authority in the classroom (p. 42), and learning environments must reflect this. As Bruner (1996) and Varela *et al* (1991) insist, it is necessary to escape the trap of deciding what is worth knowing as a license to "pre-determine how it might be best learned" (Davis, 1995, p. 43). Bruner (1996) and Varela *et al* (1991) locate the "evolving self" as the focus of pedagogy. It is in this regard that one can open the doors to different ways of looking at the world.

Thus, a tension arises between the terms "constructivism" and "enactivism." Davis (1995) sees enactivism as a way to avoid the temptation to see constructivism as a new set of methods and techniques. Broadly defined, enactivism is:

> providing occasions for (inter)action, recognizing that the students' meanings and understandings are developed through and revealed in such action. Such "occasioning" of action might be seen as embracing happenstance, in contrast to the more general tendency of avoiding it (p. 45).

The spreadsheet, database and multi-media activities represent a gesture toward a constructivistic stance that I sense draws on an ethical commitment resonated in Davis' enactivism. The sequence of activities and the basic premise of these activities parallel Davis' (1995) enactivistic orientation. Firstly, students were manipulating mathematical symbols, but not always for calculation purposes. Quite often, students were moving numbers around within a spreadsheet or database, importing numerical information from the Internet and using the spreadsheets as cultural carriers of meaning by being engaged in such activities as investigating the dollar value for goods. During the course of the activities, calculations were included. Students were required to calculate conversions of money exchange; find out the costs of buying souvenirs, compare these costs with actual Canadian prices and expressing the difference as a ratio; and, solve problems related to the dilemmas of travelling on a fixed budget, Secondly, student meanings were recognized and given a place. For example, the students were encouraged to bring their own background experiences to the activities and to use their experiences as sources of enablement. Thirdly, my role as a teacher was neither telling nor facilitating; it was a combination based on "appropriate action" that invited the students to be purposeful explorers (the teacher involved in this study did not share this same role opting to remain "the teacher").

As Chapters IV and V illustrate, there is a deliberate and systematic commitment to other constructivistic environments for students that will occasion mathematical learning. The activities I created see the teachers' role evolving from prescriptive to proscriptive (Davis, 1995, p. 52). The teachers' role in the first activity (Comparison of Exchange Rates) begins by being somewhat prescriptive, but as we move from database building to the multi-media presentation (How I Spent $5 000), we see learning opportunities move toward building a space where understandings of personal feelings and self-efficacy are given greater reign. As the activities unfold, students move toward greater self-recognition and purposeful action. As their ultimate goal, these activities have the task of inviting students to reflect on their attitudes and their sense of self-efficacy. Such an invitation is directed at opening up possibility for answering the question Davis asks (1995), "What are we that we might know mathematics" (p. 39).

The Researcher

Prior to my return to the University of Alberta, I had taught in a classroom for twelve years. I had spent my teaching career working in a large West-Central town and a large southern city, both in Alberta. Having taught everything from kindergarten through to grade twelve and subject areas ranging from a kindergarten teacher to an elementary school specialist through to junior high school math, science and physical education through to high school French as a second language and Career and Technology Studies, I returned to university to conduct research in the area of mathematics.

The realities of my years spent as a student in grade school are a major impetus for my desire to explore attitudes towards mathematics. Having been asked the question, "Are you stupid or something?" in a mathematics class one day, I was unable to answer a question. As usual, I was daydreaming. The choice was an easy one to make; I showed the teacher exactly how "stupid" I was by failing grade-nine mathematics.

During my time as a classroom teacher, I became involved with conducting workshops for the purpose of in-servicing teachers in the province of Alberta on a broad number of topics. It was at this time that I encountered Dave. After a training session, we had an opportunity to discuss what we were currently undertaking in our professional lives. I indicated that I had created a few computer-based activities and was currently searching for a school in which to conduct my research. Dave offered his class of grade-eight students, and I accepted the offer.

Dave

Dave has been involved with public schools in Alberta for the past seventeen years. During this time, he has acted in the capacity of a classroom teacher at the junior high school level in one rural Northern Alberta rural town and as an administrator in a Central Alberta town. During his time as an administrator, Dave has continued to teach in the classroom. Dave has completed both a Masters and a Doctor of Philosophy in the area of Policy Studies.

Dave is very learned in the area of classroom discipline and teacher professional growth. He has presented a large number of workshops in both these areas and has published articles related to classroom discipline. My pre-study observations gave me the impression that Dave and his class had well-established routines. The students entered the classroom, sat in assigned seats and opened books without any prompting from the teacher. Usually, there was little to no discussion among the students as they went through this process. Students were led through teacher directed instructions, answered questions posed by the teacher by raising their hands, responded when cued to do so and were then assigned individual seat work. When asked to describe his classroom, Dave indicated a need to control talk and topic in his classroom. In conversation, Dave stated, "In my classroom, you will see students doing what they are supposed to do. I usually have a definite idea about what the outcomes should look like." His classroom discipline style is fair, constant and leaves no room for negotiation.

Dave demonstrated the need to control the classroom on numerous occasions throughout the course of this study. Dave's students are very respectful of this fact and are, therefore, "model" students when in his presence. Dave's students show that they respect the rules and routines that have been established.

Corrine

Corrine is the grade eight science teacher who taught Dave's students. In order to provide the students with an extra period of computer time, Corrine allowed the students to miss four of her science classes. Corrine felt more comfortable in this role. She agreed to participate in the study at the onset but opted to minimize her involvement agreeing to offer assistance to students during the course of the study. Corrine also felt that, given the change of her role, her reflections would be of limited value to my study and, therefore, did not participate in the interviews.

The Class

A grade eight class of twenty-three students was involved in this study; fourteen of the students were female, and nine were male. The students ranged in age from thirteen to fifteen years old, with the majority of the students being fourteen years old. Prior to commencing the instructional sequence I had planned for the class, I spent a day with the students following them from class to class in order to become more familiar with the group and to gain an understanding of the class dynamics. Three of the students in the class received government funding for mild disabilities. It was during the pre-activity visit that I administered the students a pre-test of the *Fennema-Sherman Scales*. In order to administer the pre-test, I had asked Dave to leave the room so that the students would not feel uncomfortable answering questions that they might have been deemed as damaging to themselves with their classroom teacher present.

The students, who were well behaved in Dave's classroom, were not as well behaved in other classrooms. The students tended to question authority more than they did in Dave's classroom, and they exhibited more off-task behaviour with other teachers than with Dave. For instance, although a well-established routine was in place in Dave's class, in other classrooms, the students arrived and had a few minutes of "free-time" before the class began. Students were more apt to be away from their desks or engaged in off-topic conversation in classes other than Dave's.

The School

The school is primarily staffed by teachers who are closer to the commencement of their teaching careers rather than to the end of it. There are, however, a handful of teachers who will be retiring within the next five years. The school is a very lively one, where students are offered a host of lunchtime and after school activities. Students are offered a great deal of time to communicate with their homeroom teachers because there is no cafeteria in the school; students eat lunches in their classrooms with their homeroom teachers.

The school at which this study took place is a fairly new building, built within the past ten years. There were approximately 500 to 550 students enrolled in the school during the course of this study and 29 teachers on the staff. The school has an enrollment that surpasses the capacity for the number of classrooms originally built; thus, four portables have been added to accommodate the increasing number of students enrolled at the school. There are two computer laboratories at the school – one is a Macintosh platform while the other is a PC platform.

Introductory Activities

The study began in March, 1999, and continued through May, 1999, on a weekly basis of one to two 76-minute blocks (see Appendix F for a more detailed timeline). During the course of the study, students worked on spreadsheet, database and multi-media presentations. They worked on computer and web-based activities in class time; they did not do any assignments out of class time. Students were allowed to work at their own paces in completing all of the assigned activities within the scheduled class period. The tasks were modified for those students who were not able to follow the regular curriculum in that the expected outcomes were adjusted to meet the students' individual needs.

I had initially thought that I would be able to act in the role of observer but, after the introduction of the first activity, it was evident that the students would need a lot more one-on-one teacher assistance than could be afforded by the teachers involved in the study. As Dave commented after the first day of this study:

> In this activity, I didn't have that vision of what the outcome should necessarily be; therefore, I felt it was a little chaotic. I also do not feel comfortable using the spreadsheet for teaching mathematics. I just didn't spend a lot of time preparing, and I am not apologizing because I had parent-teacher interviews this week, and I had parent council and I had a few things on the go, and I did not have time, which, the research will tell you, is the biggest roadblock to any new program implementation. I was the barrier.

Due to the demand of the students on the teachers' expertise, my time was spent assisting students to complete the activities; hence, I became a participant-observer.

Introducing Spreadsheets: Comparing Exchange Rates - Day 1

During the first day of this study, the class began with Dave giving a brief overview of the lesson for the day by explaining to the students that they were to create a spreadsheet that would calculate an exchange rate. During this time, he demonstrated to students how to use the spreadsheet, but he did not have them manipulate any data themselves. Dave spent a few minutes reviewing what an exchange rate was and proceeded to give instructions so the students could hyper into the Foreign Currency Exchange Page (www.ex.net/currency/table.htm). Dave directed the students to click on "U.S. Funds" and then click on "Generate Table," which they did. He then asked students to determine how much the Canadian dollar is worth compared to the U.S. dollar. Realizing that he had asked students to create the wrong comparison table, he asked me what error he had made. I explained that the students had generated a table comparing the US dollar to all foreign currencies and that they needed to return to the selection page and click on Canadian dollar and then generate a new table. The students completed the task quite easily and were able to answer questions asked of them regarding the exchange rate between the Canadian and the U.S. dollars and the Canadian and the Australian dollars. Realizing that students were able to interpret the data, Dave proceeded with the lesson.

Students were introduced to the first spreadsheet activity, "Comparison of Exchange Rates" (Figure 4).

Comparison of Exchange Rates

Activity One – Student Instructions

Sometimes when people travel, they have to stop and stay the night in a country other than their final destination. When this happens, people usually try to stay in that country for a few days and visit a few of the sights before flying on to the country of their destination. I was lucky to have seen London, England on my way to Turkey one summer. One other summer, I stopped in Hong Kong, on to Macao, then to Singapore before finally arriving in Indonesia. There are so many other countries that you can visit as well (Lonely Planet Guide) (Yahoo Travel Page). You are allowed to spend FIFTEEN MINUTES finding and looking through one site. We are going to come back to these activities later in this mini unit.

When you travel to a foreign country, you need to exchange Canadian money for the currency that is used as legal tender in the country you are visiting.

In order to figure out the exchange rates between countries, you can visit sites such as The Foreign Currency Exchange Page. The first transaction to do is to convert CND (Canadian) to the country of your choice. On the *Foreign Currency Exchange Page*, select **Canadian Dollars** by clicking on it. Scroll down and hit the "Generate Currency Table" button. A comparison list of Canadian dollars to all countries in the database will come up on your screen.

Go to the spreadsheet, type the name of the country you will visit, and the exchange rate for Canadian dollars to the country you have selected. You then need to put in the appropriate formula for converting "x" number of Canadian dollars to any given country's currency. With this information, the necessary calculations are made to find out how much foreign currency you would have.

After this is completed, you are to put a journal entry into your math reflections about what you did in your spreadsheet. I would like you to focus on the formula that you used and how you arrived at that formula.

You will need to refer to the rubric in order to ensure that the spreadsheet is accurately completed.

Figure 4. Instructions for the "Comparison of Exchange Rates" activity. For the complete activity, see Appendix A.

Students were told that they needed to think of five countries that they may wish to visit and find the exchange rates for these countries. Next, they were told that they should pick a certain amount of money ($500 was suggested as Dave believed the students could more easily see the differences between different currencies if the amount of money converted remained constant).

Students were told that they could begin their work and that they had twenty-five minutes to find five countries, input the data regarding exchange rates and calculate the amount of money received in foreign currency. Several students commented on how hard the assignment was and that they had no idea as to how to proceed. It was at this point that my role of observer changed drastically from one of an observer to that of a facilitator – a participant-observer. While assisting students with problems, the following conversation took place; this conversation was similar to conversations I had with other students. It was because of such conversations that I redefined my role.

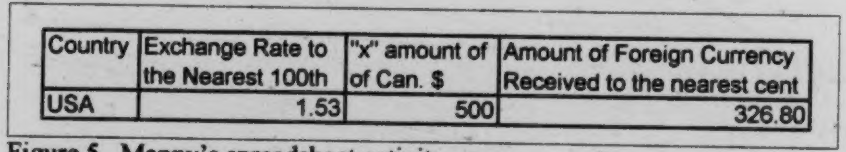
> Rick: I don't get this now, what am I supposed to do?
> Mary-Lee: Okay, now you have to select any five countries that you might want to go visit.
> Rick: Any five countries that I want.
> Mary-Lee: Any countries at all.
> Rick: I don't understand this.
> Mary-Lee: Okay. Just highlight it... Yeah... Click.
> Rick: Click here?
> Mary-Lee: Yeah.
> Rick: Click here?
> Mary-Lee: Yeah. Oops, you lost it. Click it again and then click out of it or hit enter.
> Rick: I've also got that.
> Mary-Lee: Oh, I see what you did, you merged two cells somehow here.
> Rick: What?
> Mary-Lee: You merged two cells, that means that you took two cells and made them into one.
> Rick: I can't undo the merge.
> Mary-Lee: Let's have a look... I can't either. Let's just delete the entire row. There, that should do it.

Other students were so dependent upon the teacher or myself for help that they were not able to proceed without being lead through a step-by-step process. Manny was one of many students who expressed frustration and teacher dependency when he encountered problems with entering formulas into the spreadsheet as can be found in the following interaction:

> Manny: How do I put in that formatting thing or whatever?
> Mary-Lee: Oh, you want it to the nearest hundredth, is that what you are asking?
> Manny: No, I want it to divide by or something.
> Mary-Lee: Oh, you want to put in the formula.

Manny: I want to get that thing right there (points to the formula on the board and then to the computer screen column D).
Mary-Lee: Is this your spreadsheet or (Dave's)?
Manny: That one's mine.
Dave: He's done some strange things, there's something happening to this program.
Manny: I didn't do strange things.
Dave: I corrected my self, now don't be snappy.
Manny: I didn't, I thought you messed up my computer.
Mary-Lee: So, what needs to go in for a formula?
Manny: I don't know, we're dividing or something.
Mary-Lee: What is it that we are looking for?
Manny: How much money you get from another country when you exchange or something.
Mary-Lee: So what formula are you going to use?
Manny: I don't know.
Mary-Lee: Okay, what columns are you going to use?
Manny: B and C.
Mary-Lee: And you have to divide. Which one are you going to divide by which?
Manny: C divided by B.
Mary-Lee: Why not B divided by C?
Manny: Because that's what (Dave) told us to do.
Mary-Lee: What would happen if you divided B by C?
Manny: You'd get the wrong answer.

Because of the problems that Manny was encountering with the technology and the mathematics, he was unable to complete the assignment. Figure 5 is a replication of the final piece of work that Manny handed in for this activity.



Country	Exchange Rate to the Nearest 100th	"x" amount of of Can. $	Amount of Foreign Currency Received to the nearest cent
USA	1.53	500	326.80

Figure 5. Manny's spreadsheet activity.

Some students expressed concern about being able to complete the spreadsheet activity even though the class had limited experience with a non-Excel spreadsheet activity. Aurora, a student who was very teacher dependent for completing work, stated: "I don't know how you expect us to do this work. It is way too hard, and I don't understand this equals B whatever thing. I am never going to be able to do this!"

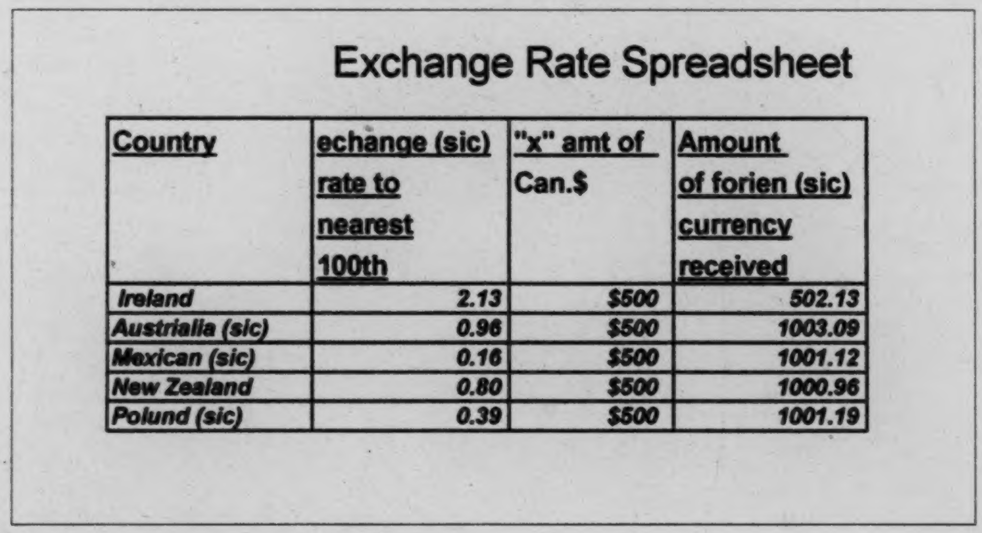
It is not surprising that almost immediately after Dave asked the students to proceed with the work, nearly one-third of the class raised their hands and had questions to ask. A large portion of the initial questions dealt with how to type headings into the cells. Seeing as no grid lines were placed around the example, the students had difficulties figuring out what information was to be placed into any given cell. Although the students had some initial experience with using spreadsheets, it seemed to be of little help in what they were doing during this particular activity.

Not all students understood how they were to import data from the hyperlink to the spreadsheet, and this was another area where Dave and I spent time helping students. It seemed to me that the students who had some previous experience with computers were more at ease with exploring the possibilities of the spreadsheet than those students who had previously not spent much time using computers. Students who became "stuck" did not seem to understand how things were functioning within the spreadsheet. Their problems are illustrated by Manny's conversation with me as shown above. Manny refused to look at the possibility of dividing one cell by another cell because, in his estimation, Dave had given him the correct formula to use. I observed the students to be quite timid about allowing themselves to explore, and every time they were required to complete a new procedure, they raised their hands in order to access teacher assistance. There was great dependence on the teacher in order for those students to learn how to navigate through the activity.

With the amount of questioning that took place, I observed students to be interested in what they were doing. As Kate indicated in her response journal when asked to describe what she liked most about doing math in a spreadsheet, Kate responded, "It's easier, and it's faster. It's more fun than doing it with paper and pencil or just doing it in your head." Another student, Janet, voiced much the same opinion as Kate by stating that, "You get to go on the Internet for, like, ages. Oh yeah, you don't have to type in a whole bunch of stuff, you can, like, drag the formula down, and it fills in the cells; that's so cool!"

Following the importing of data from the web to their own spreadsheets, I did a short lesson presentation on how to use different formats within a spreadsheet. The students were shown how to sort the information, use the fill button, change text alignment, font size and font style. Corrine entered the room halfway through the lesson and she took the role of an observer. She did not really have a sense of where the students were when she came in, and I believe that she felt reluctant jumping in halfway through. Dave was to have left after the first half of the lesson but opted to return after taking a phone call.

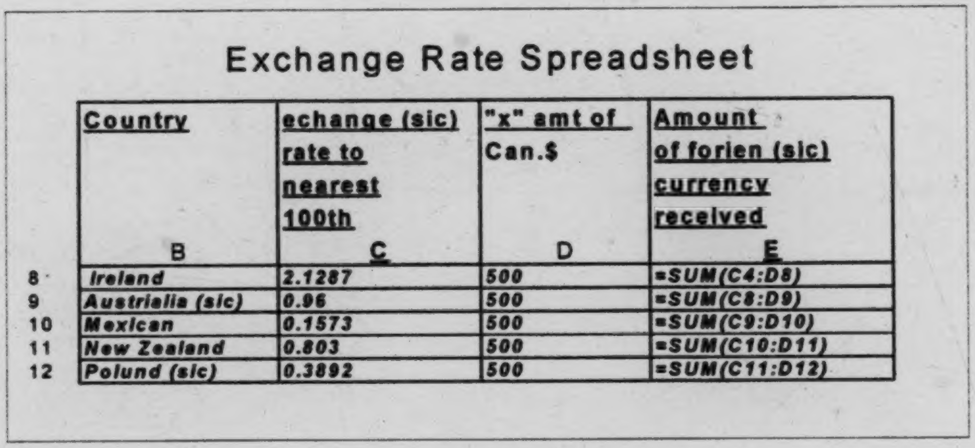
Students were given a follow-up rubric (Appendix A) and a journal entry to conclude the work they had completed during the activity with a reflection of what they had done that was mathematical and a comment about when they had been "stuck" on a particular section of the activity. It became evident to me while circulating around that the students really did not understand what mathematics they were doing during the spreadsheet activity. The students had problems associating the formulas used in the various rows and columns and how the formulas were related to which answer. Take, for instance, Rodriguez's spreadsheet assignment (Figure 6). He has not used the proper formula as he added cells rather than divide (Figure 7) nor has he referenced the correct cells, but he did not question what answers the computer gave him.



Exchange Rate Spreadsheet

Country	echange (sic) rate to nearest 100th	"x" amt of Can.$	Amount of forien (sic) currency received
Ireland	*2.13*	*$500*	*502.13*
Austrialia (sic)	*0.96*	*$500*	*1003.09*
Mexican (sic)	*0.16*	*$500*	*1001.12*
New Zealand	*0.80*	*$500*	*1000.96*
Polund (sic)	*0.39*	*$500*	*1001.19*

Figure 6. Rodriguez's spreadsheet activity.



Exchange Rate Spreadsheet

	Country B	echange (sic) rate to nearest 100th C	"x" amt of Can.$ D	Amount of forien (sic) currency received E
8	Ireland	2.1287	500	=SUM(C4:D8)
9	Austrialia (sic)	0.96	500	=SUM(C8:D9)
10	Mexican	0.1573	500	=SUM(C9:D10)
11	New Zealand	0.803	500	=SUM(C10:D11)
12	Polund (sic)	0.3892	500	=SUM(C11:D12)

Figure 7. Rodriguez's spreadsheet activity showing the formulas.

The failure to relate answers to proper cells and formulas became evident when the students wrote reflections in their journals. Manny, who had difficulties in general and had required a great deal of help, responded that:

> I used a spreadsheet and what I had in my head at the time and not much else. There was not too much done to get me unstuck except for (Dave) helped me a bit and almost got me twice as stuck (no offence). I wrote in many tables for Canada and the foreign countries and then after put the equation and solved it. Then after I put in the same thing I just pushed enter, and it did it for me.

Amelia responded with the following reflection:

> The program that we used was Microsoft Excel. I also used a spreadsheet format, and I used a few math skills. When I got stuck, I asked the teacher for help and then fixed the problem. I divided to calculate this formula.

The questions that students asked during the course of this first activity were mostly related to entering data, how they could stop things from disappearing, getting rid of such things as dollar signs, and trying to comprehend how the formula calculated the amount of money received in foreign currency, all of which are mathematical activities. As Dave commented, "The activity wasn't really if they could make it pretty but whether they had understood what it was that they had done with the math. We probably missed the boat on a few things but, by the same token, I was quite impressed with what they came up with." This comment made Dave reflect even further and declare that, during the following day's lesson, he would, "need to spend more time reinforcing the mathematical concepts that were introduced in the follow-up spreadsheet activity."

Dave's reflection of the day's activity indicated that "it was chaotic and that I didn't feel like I had control over my class. There were a number of students not doing what they were necessarily supposed to do." Astrid was one such student. Not only had she had difficulties using the spreadsheet, she had also broken up with her boyfriend over the noon hour and was of no presence of mind to be learning. Although Astrid is only one case that can be documented as to the reasons for her "not doing what she was supposed to be doing," I was reminded that, as a teacher, I should not discredit the reasons for students' inattention as it is obvious that there are many reasons for students being "off task." The impact of such reasons becomes part of the history and the culture that affect the classroom. With the amount of questioning on the part of the students, one could easily be led to believe that the classroom was out of control. On the other hand, one could envision this particular classroom as one where learning was indeed taking place because students were learning some fundamental strategies that would allow them to further explore in the sessions to come. As a final reflection, when asked about students being allowed to help each other solve problems, Dave commented that, "kids are always able to do so much more than we allow them to in this area, and it really is facilities and staff that are probably holding them back."

Second Spreadsheet Activity: Buying Souvenirs – Days 2-4

Day 2

The first of two classes used to complete this activity began with a teacher presentation of how students could put in formulas and manipulate data within a spreadsheet. Students were then given a chance to enter numbers and switch formulas around so that they could have a better understanding of how the spreadsheet performed calculations using different formulas. Students were limited to using addition, subtraction, multiplication and division during this lesson.

Dave then introduced the "Buying Souvenirs" activity to the students. He reviewed what the students had completed in the previous activity and then explained that, when people go on holidays, they sometimes buy souvenirs. He explained that usually people will have exchanged Canadian money into the monetary denominations of the country that they are going to visit before leaving on a trip. Dave also explained that when people buy souvenirs in foreign countries, they want to know how much an object costs before they buy it so that they do not pay more than what the souvenir is worth.

Buying Souvenirs

Activity Two – Student Instructions

Have you ever received a gift from someone who has been away on holidays? Usually, people bring back souvenirs for their family and close friends. In this activity, you are going to link into some on-line catalogues from different countries and select souvenirs from the catalogues. You need to select five countries from the list below and then calculate, using the spreadsheet, how much each souvenir will cost in Canadian dollars.

After you have finished this activity, your homework tonight is to find out how much the souvenirs would cost to purchase in Canada. You will need that information in order to finish the spreadsheet activity tomorrow. You can use the *Sears Catalogue*, flyers from stores, or call stores in order to find out the prices.

Figure 8. Instructions for the "Buying Souvenirs" activity. For the complete activity, see Appendix A.

Dave showed the students were they could find the on-line catalogues and reviewed the formulas that the students would need in order to complete the second spreadsheet activity. He answered the students' questions and then asked them to proceed with the assigned work.

Once again, the students' hands went up into the air almost immediately. Dave reflected upon the notion of the students' continual questioning by suggesting that the students had become "anti-manual." Dave felt that students asked questions of the teachers or those around them rather than looking for answers in a computer manual or by pulling down the help file from the computer tool bar. He attributed this to students learning "by experience or that students want to learn by someone tutoring them. They don't want to read the instructions to find out what it is that they are supposed to do." His reflections discussed the frustration that he felt by the increased teacher need of the students because the students "were asking questions that were not only (answered) there on hard copy but also on the computer, and all they had to do was read." As Dave discussed with me, he could not have imagined the demands this activity created and how one single teacher would be able to address the needs of all of the students in a classroom.

The students continued to have many of the same questions from the previous day but now had questions regarding accessing the catalogues and finding the prices quoted in them also. For example, the students found it challenging to read the British pound symbol (£) as a monetary symbol rather than an L with a line through it. Like before, students did not make the connection between the formulas and the cells that were being referenced. Furthermore, students were unable to understand what happened when the formulas were put into the various cells. The students believed that they need not consider the reasonableness of their answers as they generally felt that the computer did the work for them and that it would calculate the correct answer regardless of what the students entered into the cells. One student, Jason, calculated the cost of a wallet at three cents Canadian. When I questioned Jason as to the validity of his answer, he did not believe that the answer was wrong because that was the answer that the computer had given him, nor did he feel that he should spend any time reviewing his answers. Once the discrepancy was pointed out, however, Jason was able to ascertain that he had asked the computer to divide rather than multiply. Jason's case was not unique to the classroom. The following is an excerpt of the conversation that I had with Jason:

> Mary-Lee: Now, what are you doing here?
> Jason: I'm trying to put in the equation.
> Mary-Lee: So what does that equation give you? Just go "Enter" and describe it to me.
> Jason: Just whatever two cells you put in a division.
> Mary-Lee: Can you tell me what that means? What answer does your formula give you?
> Jason: It would cost $0.03 to buy this [a wallet].
> Mary-Lee: Now, does it seem reasonable to pay three cents for a leather wallet in any country?
> Jason: No.
> Mary-Lee: So what do you think that you might have done here [Showing him the formula] that you could change? What other formula could you use instead of a division?
> Jason: Multiplication.

> Mary-Lee: Okay. So give that a try and see what happens. Does that make more sense to you?
> Jason: Yeah, but it is still really cheap.

During our follow-up discussion, Dave gave insight as to what he felt was one of the major roadblocks that the students had encountered. In Dave's view:

> Students cannot do the math until they have figured out what the problem is. This (activity) is like giving them a word problem. We've got kids who can do columns and columns of math questions, but we give them a word problem, and they don't know what they are doing. This is just a great big word problem, and they don't know how to set it up. So I think that it probably tells us about what we know about kids at this level, that is that they have problems with word problems and that this activity is a bigger one and that they are struggling with it. The math isn't necessarily the problem.

Dave's comments resonate Schoenfeld's (1987) view that learning occurs when students assimilate new experiences to past ones so that the are able create their own meaning. In Hill's (1995) words, the computer can empower students to become better problem solvers as they become more willing to take risks. The problem remaining for the classroom teacher is that the change process is neither linear nor predictable.

For Dave, there a growing willingness to relinquish part of the control he maintained over the class as he stated that he felt much more at ease with having students wandering around the classroom. What was perplexing for him was the answer to the question: How do students solve their word problem solving skills if their peers who are helping them are going around and grabbing the mouse from the other students and showing them how to do the work?

Day 3

The first of the next two periods was spent in the regular classroom. Students were to have gone through the Sears catalogues, or any other catalogues that they could find at home, in order to find the costs, in Canadian, of the goods they had found in the Internet catalogues from the first part of the "Buying Souvenirs" activity. The first problem with this part of the activity occurred when only two students brought in catalogues. Dave had brought in four, and another six were available from the library.

Another problem was that students only had access to the Sears Catalogue, and several articles they had accessed on the Internet catalogues were not available in the Sears catalogue, and some of the articles they had located did not remotely resemble articles that could be found the Sears catalogue. Students had been previously cautioned that, if they had specialty items that were not likely to be found in the Sears catalogue, they should find the price of these articles in local stores. This part of the homework assignment was not completed by any of the students and, consequently, it became a weak link in the second spreadsheet and manifested itself as an area where the activity itself fell apart. Consequently, Dave and I spent a great deal of time trying to pull the activity together at the last minute and trouble shooting the problems associated with the lack of resources.

I had asked if the few students who had completed their assignments could go into the computer room and continue their work so that they could put graphs into their work and was given permission by the teacher who had previously booked the computer lab to do so. When the students in Dave's class arrived to use the computers, another class had arrived and occupied the free computers. Dave expressed concerned about this issue. He commented, regarding the demands placed on technology, "We are already having problems due to our thirty-eight minute periods and if we are going to do this implementation right, it is going to be hugely expensive, and that concerns me."

Another problem area arose with the lack of portable equipment. There are two LCD overheads for the school, and both are usually in continuous use. Dave had forgotten to book either of them for these classes and the amount of time trying to locate one to be returned to the computer lab would have become a logistical nightmare for a single teacher to rectify.

Once the first class was over, the students were moved to the computer room. I did not get the chance to talk to all students during the last research day and was dismayed about their lack of progress. After such a focused first day of work, the students were in need of at least one more double period in order to complete this second activity. A double period booked in the computer room would have been necessary in order to have the students complete the activity.

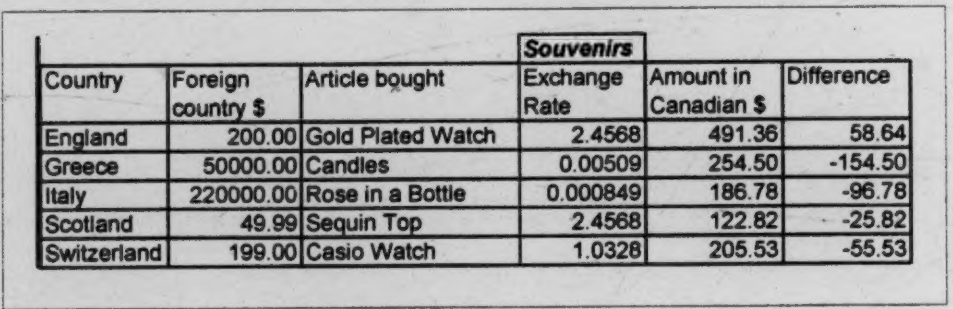
There was a lot less questioning going on in class this day; hands were not continually up all. The students were becoming a lot more independent in working with spreadsheets but, for me, the fact remained that I was dubious about the amount of mathematics with which the students were able to connect while using spreadsheets in mathematics and about how the computer acted as a calculator. I asked Jeff to respond to the question of what he would have done had no one been available to help him when needed. Jeff responded, "It's just really easy for me because I have had so much experience, and I don't need help. If I need help, I can figure stuff out on my own." Kristy's response to the same question was, "I think I know enough to try out a few different things, but I don't know if I would have gotten the right answer." Kendra recorded in her response journal that she was not sure about the prices that she had calculated for the cost of goods in Canadian currency. Even though she realized that she might have made a mistake, as can be seen in the following excerpt:

> The formulas did all the work for me so I didn't have to figure them out in my head or with a calculator; all I had to do was type them in. The long underwear that I bought in New Zealand was extremely expensive. I think I might have did (sic) it wrong because how can a pair of long underwear cost $18 155.00? That would never sell. The sunglasses and the baby's dress were cheaper, but only like $30 or so, so that wasn't too bad.

Kendra did not go back through her work to try to fix the problem with her formula that generated a cost of $18 155.00 for long underwear or with the price that she had obtained from the catalogue she had accessed. Margot felt a great deal of frustration while completing this activity. She indicated in her response journal that: "I think that this project is sort of hard. I don't like having to use all of the math things because it is sort of confusing." Kendra and Margot were always among the first students to complete their work. Although what was written in Kendra's journal does reflect mathematical understanding, she did not attempt to make the corrections without teacher intervention.

I decided not to incorporate a graph into the spreadsheet activity as I felt as though I was trying to use these two spreadsheet activities to demonstrate to the students too many of the possibilities available when using spreadsheets. The option always remained to return to this activity in order to create a graph and for students as they were invited to create the graphs for bonus marks. Included below (Figure 9) is a copy of

Margot's spreadsheet activity. The spreadsheet she created is similar to those all students handed in as their completed work for this section. Other students added details so that they resembled the first activity – Comparing Exchange Rates graphics (Figures 5 and 6), but that was not a requirement for the second activity – Buying Souvenirs.



			Souvenirs		
Country	Foreign country $	Article bought	Exchange Rate	Amount in Canadian $	Difference
England	200.00	Gold Plated Watch	2.4568	491.36	58.64
Greece	50000.00	Candles	0.00509	254.50	-154.50
Italy	220000.00	Rose in a Bottle	0.000849	186.78	-96.78
Scotland	49.99	Sequin Top	2.4568	122.82	-25.82
Switzerland	199.00	Casio Watch	1.0328	205.53	-55.53

Figure 9. Margot's "Buying Souvenirs" Spreadsheet.

Day 4

This class was spent completing the second spreadsheet activity. There was no formal instruction given to the students, and Dave and I spent the entire time circulating around the classroom answering questions and assisting students with their work. Those students who had completed the second activity were given the choice of helping a friend complete the spreadsheet activity or to start working on the database activity.

My major concern during this class was the time factor. The students were not proceeding with the project as quickly as I had anticipated. Kate, Morgan, Jeff, and Kristy were the only students who had completed the second spreadsheet activity and had stated to work on the database activity and helped other students complete the "Buying Souvenirs" activity. Still, at the end of the class, not all students arrived at the point where they completed the second assignment. Aurora was still very teacher dependent as can be recognized through the following conversation:

> Mary-Lee: So you are asking me how you are supposed to do this?
> Aurora: Yes.
> Mary-Lee: So what are you looking for here?
> Aurora: I don't know.
> Mary-Lee: Well, what headings have you got across here?
> Aurora: The exchange rate, what I am buying, the countries and all of the rest of that.

> Mary-Lee: What are your headings up here? Can they maybe help you figure out what it is that you are supposed to do?
> Aurora: I know that.
> Mary-Lee: Have you looked at them and used them to try and help you?
> Aurora: No.
> Mary-Lee: So how come you haven't been using the headings and trying to use them to help you out.
> Aurora: I don't know.
> Mary-Lee: So let's look at the first one. What does it say?
> Aurora: Which one?
> Mary-Lee: This one here.
> Aurora: Exchange Rate.
> Mary-Lee: So what does that tell you that you should be putting in here?
> Aurora: The exchange rate?
> Mary-Lee: Yes.
> Aurora: But how do I do that?
> Mary-Lee: You have to go back to the Foreign Exchange Currency Page that you were using earlier and find the exchange rate there. So just minimize the page by clicking here....
> Aurora: That's neat! What was that?
> Mary-Lee: It minimizes the page; it puts it on the tool bar but doesn't close it. It just hides it.
> [The student opens up the appropriate page and accesses the appropriate exchange rate.]
> Mary-Lee: So you are going to England; that's British pounds.
> Aurora: Okay, and now I put it in the cell, right?
> Mary-Lee: That's right, you've got it.

Aurora's need for continued teacher assistance was not unique, and several other students were still struggling with the same areas that she was.

It was at this point in the study that I began to recognize other major problems. A teaching style that was more proceduralized coupled with activities that allow for students to explore and make their own choices was creating tension in the classroom. For example, if a teacher is unwilling to allow students to help each other "catch-up," and the teacher believes that all students should commence a new activity at the same time, there is bound to be tension in the classroom and, consequently, discipline problems may occur.

Even though there were a few discipline problems, students were far more on task than I had anticipated them to be as it was April Fool's Day, the last block of school before a school dance and the last day of school before the spring break. Students such as Astrid, who had problems concentrating at the best of times, asked to go to the washroom three times during the course of the two periods. Other students, such as Manny, began to pay less attention to their class work and were less than willing to complete the work. They used such phrases as: "I don't feel like finding another one," and, "I can only find three things; I don't want to look any more," to express their lack of concentration or a lack of interest towards the day's work. This was the first time that the students had raised any of these types of concerns or comments and, consequently, Dave viewed this as the beginning of discipline problems in his classroom. As he commented after the day's session:

> Today there was significantly more off-task behaviour than on previous days. The focus wasn't there, probably for a lot of reasons. Reason number one is that it is the final day before Easter Break, we're having a dance, the hormones are running crazy; it could also be the reason that they have been sat on all morning and being given test after test because other teachers view them as being hard to deal with, and they are ready to unwind. So that could be part of it because as I think about it further, the first thirty-five minutes went by very, very well, but I never even let kids go to the bathroom in my class, and I had seven requests today. I don't know if it was work avoidance mode or what it was, but there certainly was less attentiveness than normal with regard to what was going on in the class.

Perhaps the discipline problems that Dave was concerned about were due in part to the lack of instruction and a break from the regular classroom procedures and in part that the students were allowed to help each other complete the activity. The students were to "sink or swim" on their own, but when they started to sink, they asked each other for help which, in turn, increased the noise level in the class.

Dave began to show signs of not needing to control the students as much as he had in previous days. He allowed the students to help each other to complete their assignments and purposely did not give directions for the database activity. He mentioned that he would not give directions for that assignment, which I had no problem accepting. As a final reflection regarding this section, Dave stated:

> Typically, when using computers, we treat students like they are so helpless. and everything becomes perhaps such a perspective type of

> instruction and I don't think that we have allowed the learners in the labs to become self-sufficient and to experiment. It is because we don't want them experimenting - to go beyond our boundaries and, thus, they are into areas that we think they ought not to be into to complete our assignments. Giving up that sort of control is going to be extraordinarily difficult. I think that it is the teacher's climate of how we have set up in the classroom that is limiting the students and has limited students in the past. This whole type of technology that we are going into right now is going to be, in a sense, giving up a lot of our control. I think that there has been a climate of control established in the classroom, and I think that it is going to be a chore for me, certainly, to start giving up that control and letting the students find better ways to do things than I am capable of myself. I need to start looking at things differently, looking at the whole thing differently so that the students are striving for excellence at their level, which is going to be over and above my level of excellence. It is probably the first time that I have ever been confronted with this in a classroom situation. That is going to be a struggle for me, but I think that I still have to be pretty firm and have established routines in the lab that keep the students on task.

The Database: Organizing the PowerPoint Presentation – Day 5

For this activity, the students were to enter information they had found regarding five possible tourist destinations into a template database. This information was to be made available for all students to use, but Dave did not want to add this component to the activity, citing time as a factor. Dave decided that this activity would be used for bonus points as not all students were finished the spreadsheet activities. I agreed to the change as the database activity was the one that was the least mathematics related. Rather than sharing the information, students used the database to organize their thoughts so that they springboarded into the multi-media presentation.

I gave the students directions as to where to find the template and how to locate the five records in the template (Figure 10), and the students were told to start their work.

Organizing Information in a Database

Activity Three – Student Instructions

In the next activity, you will be asked to work on a database. The fields for data entry have already been established for you, but you will need to enter specific data into the records. For this task, you and a working partner will need to select five countries to visit, and you will need to find out how much one dollar Canadian is worth in each of those five countries. You then need to access ClarisWorks through the start icon on the bottom tool bar. You will need to open the document named, "Planning A Trip Template." Once this is completed, you will need to start entering your data. You need exchange rates, the year you want to travel, whether visas or passports are needed for travelling within that country, information regarding immunization and the answer to your calculation of the percentage difference of what you might buy for a souvenir. Don't forget to use the rubric.

Figure 10. Instructions for the "Organizing Information in a Database" activity. For the complete activity, see Appendix A.

During Day Five's classes, I was alone in the classroom as Dave was called away because of a school crisis. This was not a problem as the students knew me well enough that I did not have to spend time establishing a presence in the classroom. I found that the students seemed to be losing interest in the activities and wondered at the possibilities of attitude or motivation as being the underlying cause. As Bruner (1996) argues, mathematics is best learned within a cultural milieu that places equal importance on the students as well. For some students, the database activity could have been lacking the cultural component that is a vital part of learning. This could be in part because there were a few students who were still working on the spreadsheet activities, and those who were working on the database activity received very little direction. Dave reflected on the dilemma I had with the lack of energy displayed by the students during our debriefing:

> The kids have a lens that they think that everybody should be moving forward at the same pace. Maybe it's so ingrained in them that they must all move together at the same rate that kids don't know how to move ahead. Like, there's hours and hours and hours of activities that they could have continued on. Nobody said that they had to stop, but instinctively they thought, "I'm getting too far ahead; I have to slow it down."

On the other hand, I was given the impression that the database activity was redundant and not as practical as I had once thought it would be. Jeff commented that the activity was "like taking the stuff from the spreadsheet and typing it into a database." Aurora remarked that, seeing as the assignment was "not for marks, why should I waste my time doing it?" I also believe that the information collected from year-to-year will be of greater value as it will allow students to analyze the data their peers collected over a longer period of time.

Kristy, a student who was always on task, spent a great deal of today's session off task and talking with Manny. Kristy indicated that she thought, "The database is a really dumb activity. I don't see why we have to do it 'cause I just want to get to the PowerPoint activity. That will be a whole lot more fun." Jon indicated his disapproval by simply stating, "This is dumb!"

Perhaps the lack of enthusiasm was a reflection of Dave's attitude. He expressed his feelings about not being very excited about the project after he realized how teacher demanding it was. Dave stated, "Well, I'm more jazzed about it than when I started it. Part of the problem is that, as an administrator, I'm the last person on the timetable. For me to make detailed commitments to a particular course is almost laughable because I may never teach this particular course again." I believe that the lack of presence of the regular classroom teacher could have also played a role in the students perceived attitudes and motivation towards the activity. It was disheartening for me to see the students less energetic than in previous days. Yet another reason for the lack of student motivation could have been that, since the activities were presented in an instrumental way, the students were not occasioned to create their own meaning. They were merely guided toward the teacher's sense of what knowledge is and what is worth knowing.

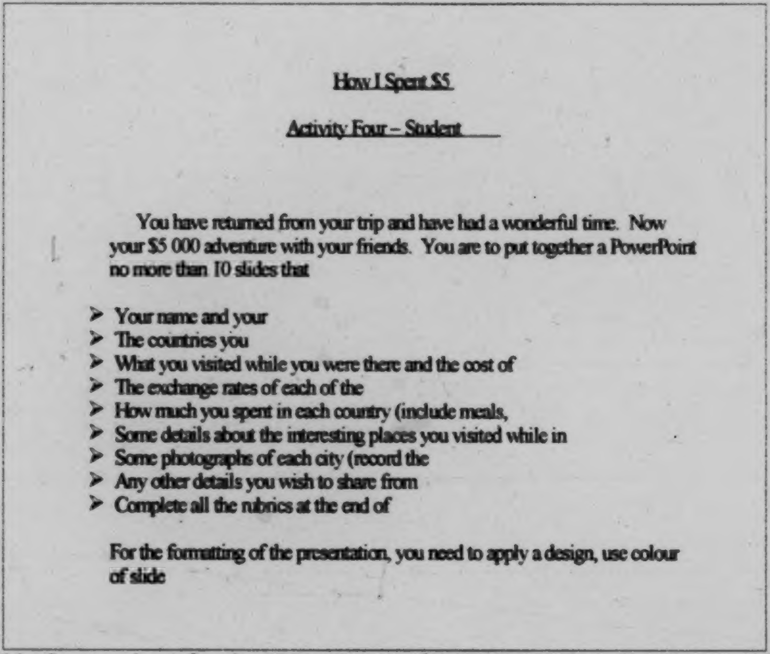
The students seemed to be unable to maintain focus on the task. Manny and Kristy were not the only students to exhibit off task behaviors. At one point, Lorne reached over and turned off Kendra's computer, thus deleting all of her database work. When I asked Lorne why he had done that, he responded with a glib "I don't know." When pressed further Lorne said, "I am bored. I don't like this database thing that we are doing, and the Internet is really slow."

I found this activity to be long and laborious as a result of the students' behaviors and comments. I began to feel as though I wanted to push the students to get them to finish up the database activity as well. I was also starting to become concerned about those students who were still finishing the spreadsheet activities and wondered if they would finish them. Students had problems with this activity in that they were unable to save the information that they had entered into the database. Martin commented, "I had put in all the stuff, but it erased, and I had to do it all over again." Allan had the same problem: "Well, first of all, all my stuff erased so I had to do it all over again, and then I did it in ClarisWorks, and I had to do it all over again in Microsoft, and then other hard stuff was that I could go into Jamaica and stuff like that on the things so that was kind of hard."

I believe that the students were not motivated by the database activity and, therefore, they were not engaged in purposeful learning as the students were not performing beyond their capabilities since they had a template available for them. They had little more to do than search for information and type it into the appropriate line. This would not be challenging for the students, especially those who indicated that the work was dumb or boring. To me, the students were able to understand in terms of, as Vygotsky (1987) suggests, the need for students to have coherent and unified structures that support learning within the "zone of proximal development." For Vygotsky, it is necessary for learners to acquire both symbolic and practical skills in order to live in symbioses with more competent members of society. The students' statements indicated to me that they had not acquired a sense of agency and efficacy (Vygotsky, 1987). The students understood the concept of how to use the database, and they did not have to have the concept reinforced through using a template.

PowerPoint Presentation: How I Spent $5 000 – Days 6-8

Dave introduced the final activity for this unit of instruction (Figure 11), and students were then instructed that they were allowed to work either with a partner or alone.



How I Spent $5

Activity Four – Student

You have returned from your trip and have had a wonderful time. Now your $5 000 adventure with your friends. You are to put together a PowerPoint no more than 10 slides that

- Your name and your
- The countries you
- What you visited while you were there and the cost of
- The exchange rates of each of the
- How much you spent in each country (include meals,
- Some details about the interesting places you visited while in
- Some photographs of each city (record the
- Any other details you wish to share from
- Complete all the rubrics at the end of

For the formatting of the presentation, you need to apply a design, use colour of slide

Figure 11. Instructions for the "How I spent $5 000" activity. For the complete activity, see Appendix A.

Dave seemed to be a lot more comfortable with what was happening regarding technology integration in his classroom as well as with the amount of energy generated by the students in his classroom. The entire flavor of the class changed so much from the first day that I was introduced to the class. Dave commented that:

> I see that they, the students, are developing a greater sense of efficacy and self-sufficiency with regards to the task, and it has taken two months to get there, which, if you are a teacher, is a lot of patience. You have to go through that being out of your element, you have to go through a performance dip, you have to go through a sense of being overwhelmed and, quite frankly, had you not been here every week, forcing me to go back to the assignment, I would have probably bagged it a month ago. I think it speaks a lot about teacher change and how the technology clashes sometimes with

> embedded philosophies with regard to classroom climate, classroom discipline, classroom order and the way things have to be in middle grades and traditional classes but don't necessarily have to be in technologically related classes. We tend to try group work and try cooperative learning and try those types of activities, and we tend to dabble in them, but we don't give them any more than lip service.

The students have moved from sitting behind their own computers with hands raised, quietly waiting for the teacher to come over to answer questions, to the point where the students are able to answer their own questions or ask each other students for help; the students have become a lot more autonomous. Dave relinquished a lot of the control issues to the students, and I believe that this action has influenced how the students view the work that they are doing in the lab. Dave answered questions regarding control issues by stating:

> I think that it is the teacher's climate that we have set up in the classroom that is limiting the students, have limited the students in the past, and that this whole type of technology that we are going into right now is going to be, in a sense, giving up a lot of our control, like I have started doing. I still have a long way to go but, because of the things that have happened in the lab, kids screwing around and vandalism and those types of things; I think that there has kind of been a climate of control established in there, and I think that it is going to be a chore, for me certainly, to start giving up some of that control and let kids find better ways to do things than I am capable of doing myself. I need to start looking at it differently, looking at the whole thing differently so that they can do that because they are striving for excellence at their level, which is going to be over and above my level of excellence.

The students seemed a lot more involved with what it was that they were doing during this activity although Astrid and Denise became so frustrated with what they were doing that they got very little done during the double class period. They were trying to find out the price of airline tickets, and they could not see what they were supposed to be doing or how to organize themselves to get the task accomplished. It was only when Corrine arrived that Astrid and Denise were able to get the amount of help that they needed in order to be able to work on the activity. Corrine spent the full thirty-eight minutes with the two students while Dave and I helped the other students with their work. Dave and I had tried to give Astrid and Denise some pointers to get them steered in the right direction, but they were totally unable to use the information to get themselves on track. As Astrid commented, "I hate computers. They are really dumb, and I don't see why we have to use them in math class. I am no good at using computers."

At the end of the seventy-six minutes, five students were so engrossed in the activity that they had not realized that the two periods had passed. Dave mentioned this during our conversation following the session: "First of all, we gave them reminders; that is, there's ten minutes until the end of class, the stuff is due at the end of next week, telling them the computer times, and they all kind of nodded their heads and went on. At the end of the class, at least four different kids said, "Do we get to stay through science too?" The time passed so quickly for them that they didn't realize that they had science already, and then there was a bunch of them that couldn't believe that it was now break time." Reflecting back to Vygotsky (1987), the "zone of proximal development" was wide enough for the students to acquire a sense of agency.

The amount of questioning by the students was less frequent than in previous classes; it had been going down steadily but, during this day, it seemed more apparent than before. Rather than running around trying to put out fires, I had reached the point that I could ask students to talk to me about what they were doing in class.

I think that one reason for the lack of enquiries was that the students had used PowerPoint before so they had some level of expertise and confidence using the multi-media presentation software. Perhaps the fact that students had been encouraged to find out the answers for themselves, which is what Dave had been doing with the students in order to complete this and the database activities, may have increased the student's agency and involvement to the task. Some of the students still asked how to do the conversions, and Dave continued to help students in a proceduralized fashion.

Talking to the students about how they felt about what they were doing was much more positive than at any other time during the course of the study. Other positives included the following: the discipline problems that were starting to arise had all but vanished during the last few weeks, and the students had become much more self-disciplined and self-regulated in order to get work completed.

Interpretations and New Questions That Arise

After completing the activities, I could see many themes emerging in the classroom. Some of the patterns pointed to changes in students' attitudes and feelings of self-efficacy while others had implications that could possibly have some impact on students' attitudes and feelings of self-efficacy. I have discussed these issues, as well as a more detailed analysis of my findings, in Chapter VI. In what follows, I will discuss implications regarding the instructional sequence, on task student behavior and resources.

I believe that the students should have been given more preliminary details of how calculations in a spreadsheet work before first diving into the task. This could have been easily accomplished by having students type numbers into cells and then having them complete practice of using addition, subtraction, multiplication and division in a spreadsheet scenario. It would be the goal of this preliminary work to accustom students to using spreadsheets and to enable them to become familiar with how data can be manipulated within a spreadsheet.

I was discouraged by the lack of what I perceived to be enthusiasm shown by the students because I thought that the students would really enjoy the database activity. I wondered if, by extending the project over several weeks, the students did not see themselves progressing fast enough. The lack of the students' enthusiasm might have also been due to the two-week hiatus they had had from the project before beginning activity three. Perhaps this is because there was too much of the same work being repeated, and the work was becoming too mundane. Perhaps the activities were becoming more like regular classroom seat work with the difference being that the seat work had been moved to a computer lab. Perhaps it was in part due to the teacher's attitude. I believe it is a combination of all of the above.

If students are going to understand what it is that they are being taught, then they need time to manipulate the information that they are receiving. This is the basis of constructivism and best teaching practice. Given what needs to be covered in the classroom according to the curriculum, teachers feel uneasy relinquishing a great deal of time for students to experiment with newly introduced material. The process is one that effects both students and teachers in that both groups need time to experiment. Dave expressed his frustrations regarding implementation time. He commented that:

> I lectured the administrators…about being patient and accepting performance dips and understanding that if the underlying beliefs and philosophies are most difficult to change with teachers in order to have them incorporate new curriculum, then there was a need for greater tolerance of more chaotic classrooms. I was in the middle of a performance dip today, and it was a cause of not extreme anxiety but anxiety, certainly. Had I been a teacher and had I had an administrator in there evaluating that, I would have been extremely uncomfortable.

A single class period in the computer lab was really not conducive to getting a lot done when one takes into consideration settling into the computer lab, logging on and accessing the files. Another problem was the slowness of the computers about which two students, Janice and Denise, commented. They became frustrated at the computer crashing and at the amount of time that it took information to download from the Internet. A major reason for the computer problems was that the other lab in the school had been closed during the previous day's session. With the Mac lab open there was a possibility that the students in that lab were using the Internet as well as Dave's class, in the PC lab. Also, with a division-wide server, the system became much more taxed by the number of users, and computer problems are likely to result. Dave felt much the same way as the students did as he stated, "It bothers me when the technology messes up."

Dave estimated that it took students an average of ten minutes to move from any given classroom to the computer lab, to settle in and to log onto the machines before classes could commence. To me, this is a vast amount of time to lose, and the effects are compounded when the technology does not co-operate nor cannot function within the demands placed on the server.

The students seemed to be quite on task and willing to try something new although the question of whether or not this was the newness of the activity that can be cited as the reason for student participation and the on task behavior demonstrated by the students. From what I had observed of the class during my pre-study contact with the students, they tended to be easily distracted and, as a consequence, needed to have very rigid parameters set.

As it is rather difficult to control what another teacher does, it is suggested that a school institute a schedule for computer usage, including the number of students accessing the computers at any given time.[4] In this way, teachers can avert trying to access a computer lab that is already in use, or teachers would have an idea of how many computers are available for other students to use. This means a great deal of orchestration but, the end result would be that teachers have an indication of the number of computers available at any given time. Because of the limited number of resources, hopefully teachers would be able to resolve conflicts before they occur. The logistics of trying to operate a school of five hundred students with two computer labs that are used at one hundred percent capacity each period of the day with no computer facilitator is a formidable task.

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[4] Depending on the philosophy of the school, such scheduling is not required. Take for instance a project based school in Alberta that operates with a ratio of one computer per five students. Students are engaged in project based learning as their main form of instructional design. Computers are accessed on a 'need to use' basis rather than be the implementation of a regimented schedule. This strategy has been successfully implemented since 1997.

V. STUDENT STORIES

Overview

Chapter VI will present the reflections of three students towards the activities. Following this description is an analysis of four questions that showed slight changes between pre-test and post-test scores on the *Fennema-Sherman Scales*. I will explore data collected as it relates to the four *Fennema-Sherman Scales* used in this study. For the purpose of this section, the reflections presented were collected through classroom comments, journal entries and the final interviews.

Three Journeys

The following section will describe three students who participated in the study. I will concentrate on describing the students, followed by a description of their multimedia presentations. In order to show a broad spectrum of classroom abilities, the students selected for this section handed in a high quality, an incomplete and an unsatisfactory PowerPoint project. The PowerPoint project represented a place where students could make mathematical meaning and be involved in the manipulations of symbols without making overt repetitious calculations (Davis, 1995).

Paula: New York and San Francisco

Paula is a very quiet and reserved girl. She did not interact with other students when in the classroom setting nor, according to Dave, did she associate with others outside of the classroom setting. On a daily basis, I observed Dave's remark to be accurate. Paula did not work with other students when completing any of the assignments, nor did she often interact with other students during class time unless they asked for help. Jeff said, "I just wanted to ask a person like Paula or Martin or Jarek when I needed help rather than ask the teacher for help." Paula has been living in Canada for the past two years after moving from Vietnam. Paula's English is excellent although she has some problems with enunciation and omits the occasional word when speaking.

Paula's marks are always in the top five percent of the class. She is not involved with extra curricular activities, spending most of her free time reading or watching television.

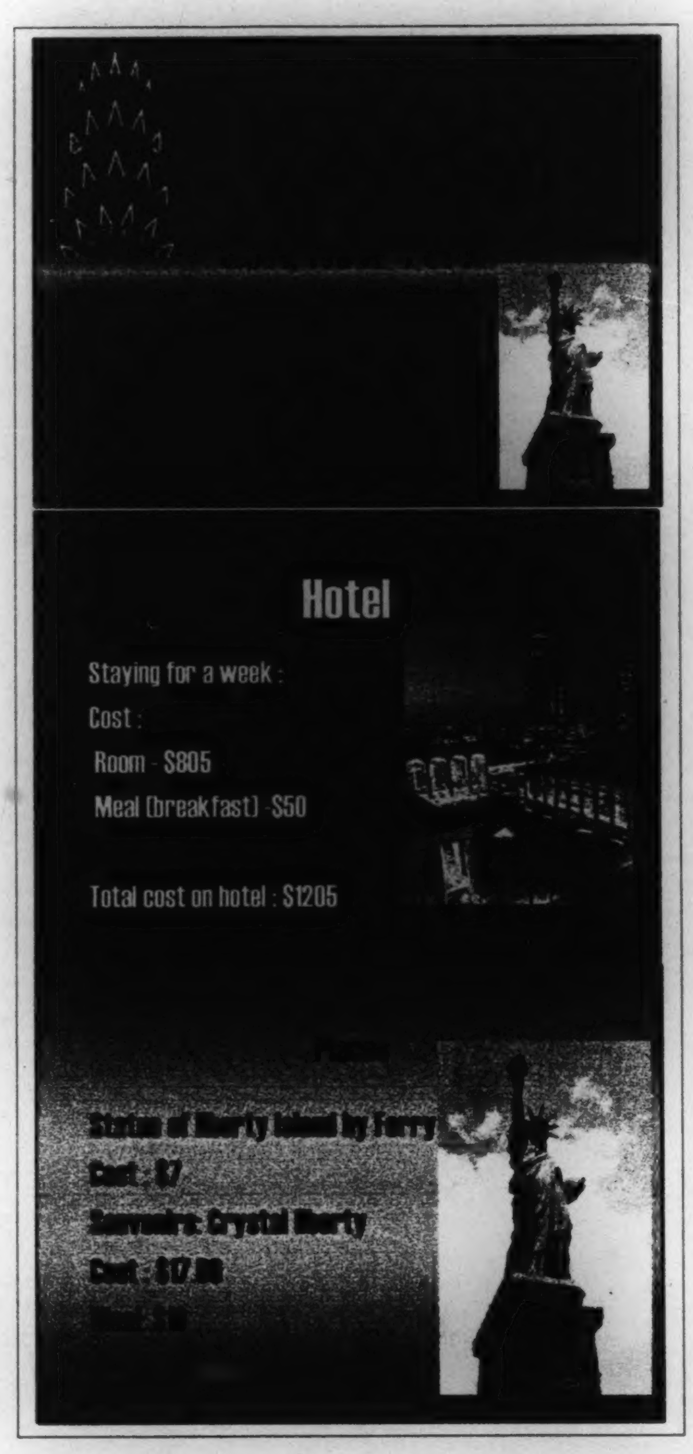
Paula rarely posed questions to the teachers when she had a problem with the work, preferring to find answers on her own. When questioned about how she proceeded when unable to answer a question, Paula responded, "I'll just do another question. I'll just leave it." She continued to explain, "When I am finished the other questions, and that one is left, and I am done the other questions, then I will just go back to the other question." To me, this demonstrates that Paula has a lot of self-confidence when completing mathematics problems. My observation was reflected in Paula's response to the *Fennema-Sherman Scales*. On the scales regarding confidence in mathematics, Paula scored all positive statements in the agreed column in the pre and post-tests and all negative attitudes for both the pre- and post-tests were answered as disagree.

Paula preferred the PowerPoint activity simply because, as she stated, "I like PowerPoint." A greater proportion of the students commented that they preferred the PowerPoint activity. For students like Paula, PowerPoint gave them a sense of freedom and autonomy; they could "play around with stuff" and "look at different things." Jarek mentioned that he got to look at "cars and (Dave) can't say anything about that!" Paula did indicate that, "the other ones were quite easy, and this one is for, like, research for the price and stuff makes it kind of like harder." However, Paula was not deterred by this and almost took it as a challenge, indicating, "In looking, it sometimes, when you are looking for the air ticket's price, it's kind of hard. They didn't talk very much about the price." Paula did indicate that this negative side of the activity did have a positive one for her: "You could see, like, how much it costs when you really need to travel, and you have to do it on your own and stuff." Thus, Bruner's (1996) notion of how culture and mind are inextricably linked is re-articulated in Paula's words as she was able to link the outside to the classroom learning environment.

Paula made connections of the mathematics she was using in class to its usefulness in the world outside of the classroom. Her responses on the *Fennema-Sherman Scales* reflected this as well as a comment she made during the final interviews in which she said, "Math, you can use anywhere when you live until you are old and stuff. You use math always." In both the pre- and post-tests, Paula disagreed with all negative statements: "Mathematics is of no relevance to my life; Mathematics will not be important to me in my life's work; I see mathematics as a subject that I will rarely use in my daily life as an adult; Taking mathematics is a waste of time; In terms of my adult life, it is not important for me to do well in mathematics in high school; and, I expect to have little use for mathematics when I get out of school." Her responses shifted from agreeing with the following statements on the pre-test to strongly agreeing post-test: "Knowing mathematics will help me earn a living; Mathematics is a worthwhile and necessary subject; and I will use mathematics in many ways as an adult." Paula moved from neither on the post-test to agree on the pre-test when responding to the following: "I will need a firm mastery of mathematics for my future work." There was no change recorded for answers to the following: "I will need mathematics for my future work (strongly agree); and I study mathematics because I know how useful it will be (neither)."

I believe that Paula had a very positive attitude towards mathematics and self-efficacy at the onset of the activity as well as at the end. The results of the attitude test also demonstrated this to be true. Insofar as using computers to complete mathematics activities, Paula moved from a scoring of neither for all statements in the pre-test to a scoring of agree for the first three positive statements and to a disagree for the first four negative statements. Paula did, however, indicate on the test and verbally that she felt that, "When you just do it (mathematics) on a computer, when you just punch in the numbers, and it (the computer) will do it for you, but when you do it (mathematics) on a paper, by yourself, you can see what you did wrong and stuff." Paula was not the only student to make this remark; Martin, Kristy, Jason and Charlotte mentioned this during the follow-up interviews. This statement could, therefore, indicate a lack of confidence on the students' part towards using the computer to do mathematics, a lack of understanding of what happens when the computer calculates an answer, or a poorly formulated statement on my part that does not truly reflect students' confidence when using a computer for mathematics.

Paula was one of the twelve students who was able to complete all of the activities in the time allotted although she did not extend the trip to two different countries (see Figure 12). Rather, Paula visited two states in the United States of America.



Hotel

Staying for a week :

Cost :

Room - $805

Meal (breakfast) -$50

Total cost on hotel : $1205

[illegible]

Statue of liberty island by Ferry

Cost : $7

Souvenirs: Crystal liberty

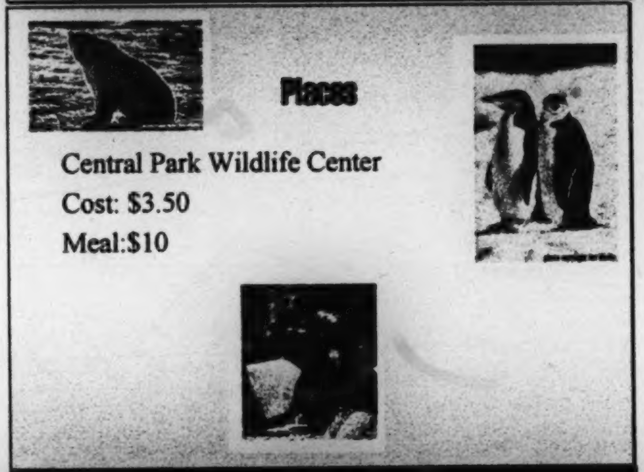
Cost : $17.[illegible]

[illegible] : $[illegible]

[illegible]

Souvenir: Crystal Empire State Building

[illegible]

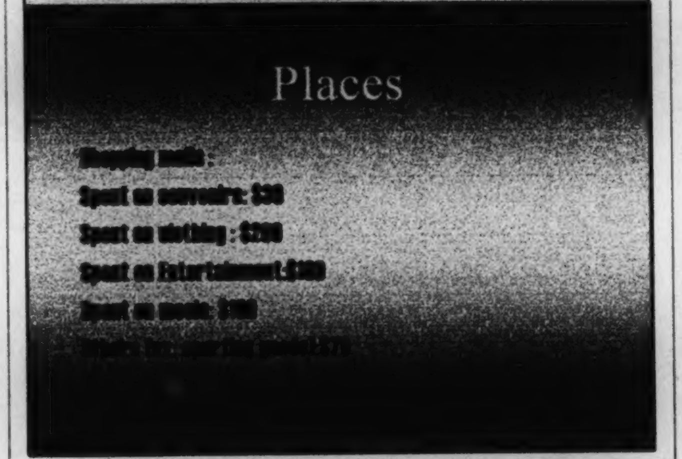


Places

Central Park Wildlife Center

Cost: $3.50

Meal:$10



Places

Shopping malls :

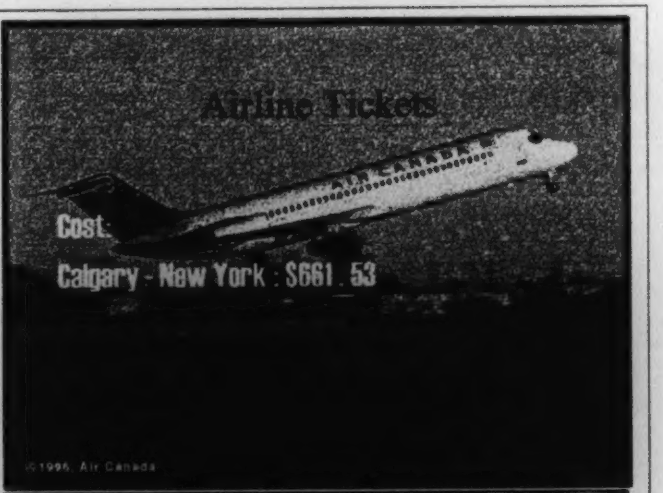
Spent on souvenirs: $30

Spent on clothing : $200

Spent on Entertainment:[illegible]

Spent on meals: [illegible]

[illegible]



Airline Tickets

Cost:

Calgary - New York : $661 . 53

©1996, Air Canada

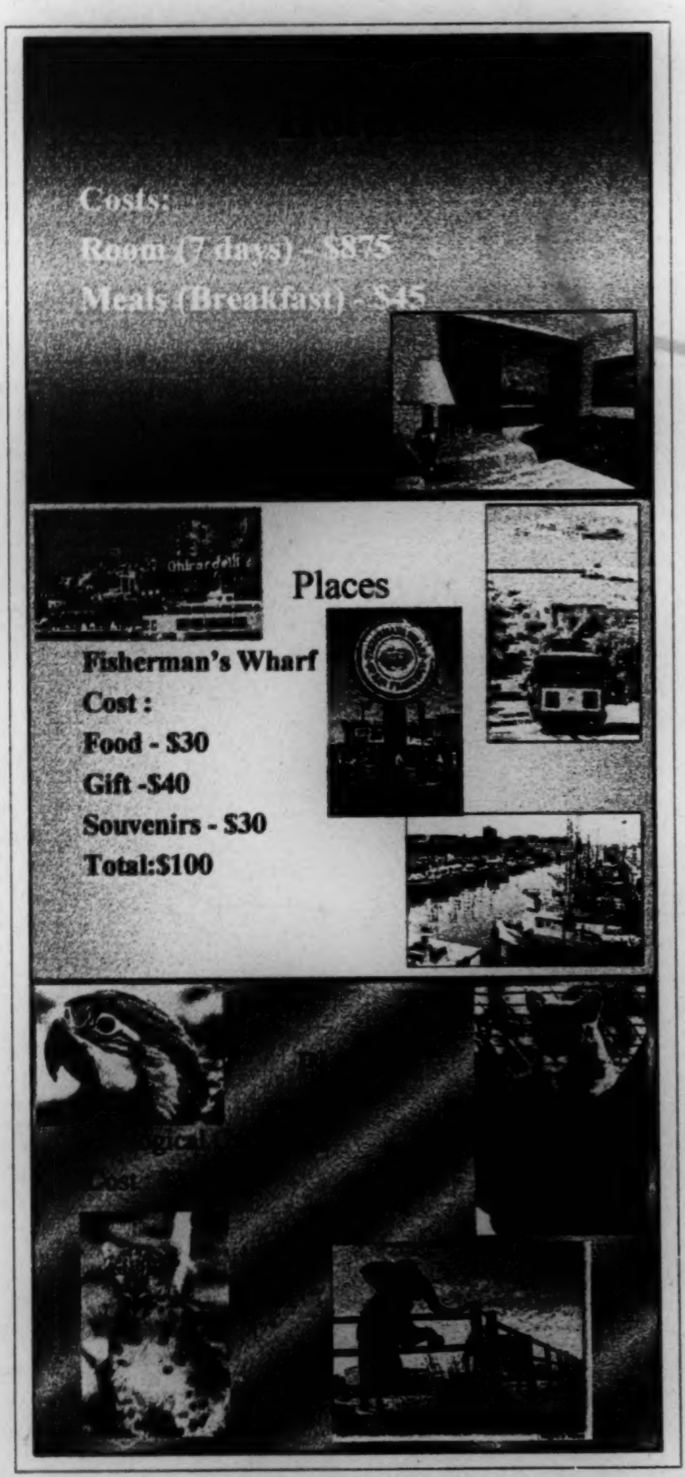
Car Rental

[illegible]

[illegible]

[illegible]

San Francisco,California



Hotel

Costs:

Room (7 days) - $875

Meals (Breakfast) - $45

Places

Fisherman's Wharf

Cost :

Food - $30

Gift -$40

Souvenirs - $30

Total:$100

[illegible]

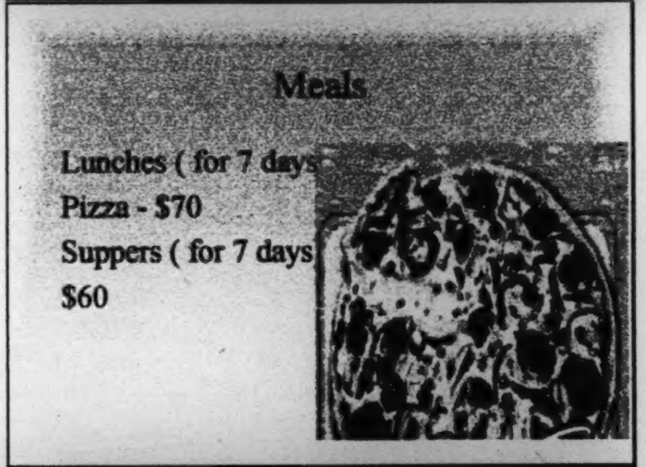
Cost

Ghirardelli

Shopping on clothing :

Outlet stores

$250



Meals

Lunches (for 7 days

Pizza - $70

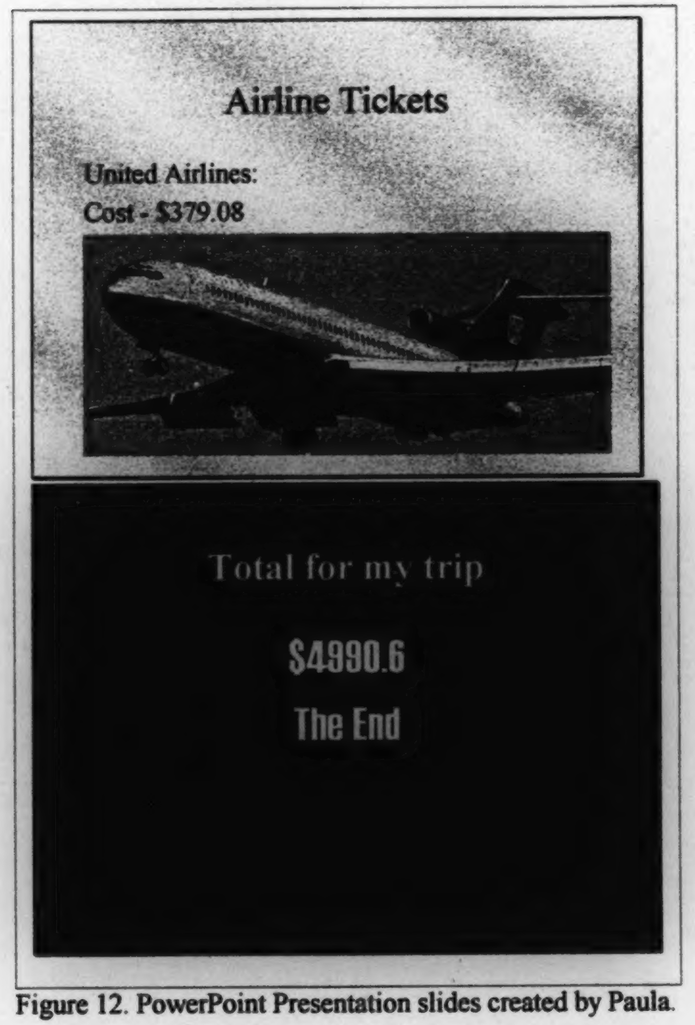
Suppers (for 7 days

$60

[illegible] Rental

[illegible]

7 days = $315



Airline Tickets

United Airlines:
Cost - $379.08

Total for my trip

$4990.6

The End

Figure 12. PowerPoint Presentation slides created by Paula.

In her PowerPoint presentation (Figure 12), Paula included all of the requirements. She quoted costs in Canadian dollars after making the necessary conversions. She accessed the cost of meals, hotels, airline tickets, souvenirs and attractions to visit. Paula costed out her trip and made decisions as to what airline she should fly, what hotels were within her budget as well as how long she would be able to stay in the cities visited.

Jason: Nepal

Jason was another quiet student in the classroom. He preferred to work on his own and did not interact with other students in the classroom. Dave described Jason as: "a whiz-kid computer nerd who was satisfied with completing only two thirds of his work, in any class, because he knew that would be enough to get him by." When asked about Jason's homework habits, Dave replied, "Jason doesn't do any homework. We get no support from his home in order to do work. If it doesn't get done at school, it doesn't get done at all." One of Jason's peers referred to him as "a walking dictionary" during the post project interviews. Jason's hobbies include playing on a computer, reading and watching television. He is not involved in any extra-curricular activities.

Even though Jason's "work ethic" might not have been up to what a teacher would expect of a student with Jason's potential, his marks rank him at the middle of the range of his class' marks. His positive attitude toward confidence in mathematics was reflected in the pre-test and post-tests of the *Fennema-Sherman Scales*.

Jason's response to one statement, "I am sure I could do advanced work in mathematics," shifted from the pre-test from "agree" to "strongly agree" as well as its negative counterpart, "I do not think I could do advanced mathematics," from disagree to "strongly disagree." This statement dealt with his ability to do more advanced mathematics, an aptitude that Jason saw as one he could easily attain. He gained more confidence in his mathematical ability during the course of the study as he commented during the interviews, "I really like math, and I'm getting better at it."

Jason had initially viewed mathematics as having a limited impact on his future life. His responses on the pre-test demonstrated a negative view toward the usefulness of mathematics. During the post-test, Jason shifted to a more positive attitude regarding the usefulness of mathematics. Jason felt that the reason for this change was due to "doing units in math that are about things I know. Like, we are doing baseball stats and stuff like that. That (the change) could also be because we moved to an easier unit."

Jason felt greatly challenged during the completion of the PowerPoint activity. He indicated that the challenge he found in the PowerPoint activity was that, "it's limited to $5 000 dollars and you have try to plan a trip to two countries without going over that amount," but he stated that, " I really am having a lot of fun trying to figure out where I can go." Coupling this remark with the amount of detail that Jason included in what he was able to accomplish in his PowerPoint presentation, I wonder, "Could it be that Jason tended to take on a problem and find an answer regardless of how long it took him to complete the work?" Perhaps this is how Jason operated as a learner – being very thorough at answering questions and not leaving himself time allotted in class to complete the work that was to be done. This fact alone might explain why Jason was content with completing two-thirds of his work – because what he finished was always meticulously completed.

Jason expressed disappointment about the PowerPoint activity by stating, "There is not enough time to do it." Jason indicated that the feeling of running out of time was the major source of frustration he had encountered while working through the project. When asked how he felt when working on a hard question, Jason answered, "It makes me feel as if I am going to run out of time" because "it just takes longer." Although this seemed to frustrate Jason, he continued to work independently, at his own pace, throughout the study.

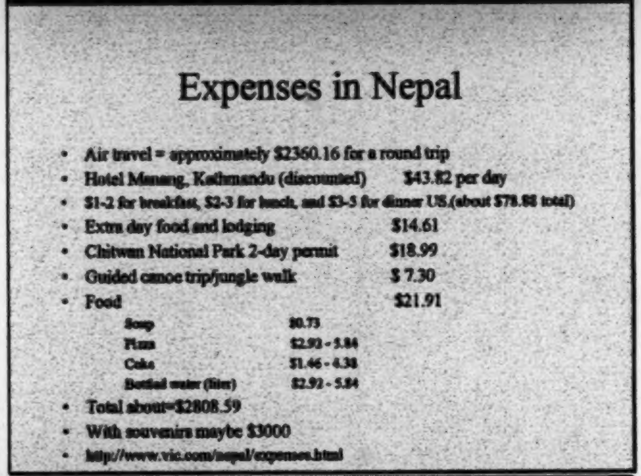
Although Jason indicated that he enjoyed using the computer to do mathematics, he concluded his statement with the following: "Actually, if you are on the computer in math, it takes more time because it is hard to become independent and to having the formula there when you need it and, when you are in an ordinary math class, it's in your head, and you can just do it." Jason attests that it is challenging for him to remember the formulas when using a computer rather than relying on a piece of paper to which he can refer back in order to answer a given question.

Even though Jason was meticulous regarding some of the activities he completed, he did not always pay close attention to the answers he produced in such things as the spreadsheet (see Chapter IV) and was not able to complete all assignments. He completed the two spreadsheet activities but did none of the database activity. He was only able to complete the first four slides for the PowerPoint activity (Figure 13) but he included a great deal of information on the slides.

Jason's

Australia

Nepal



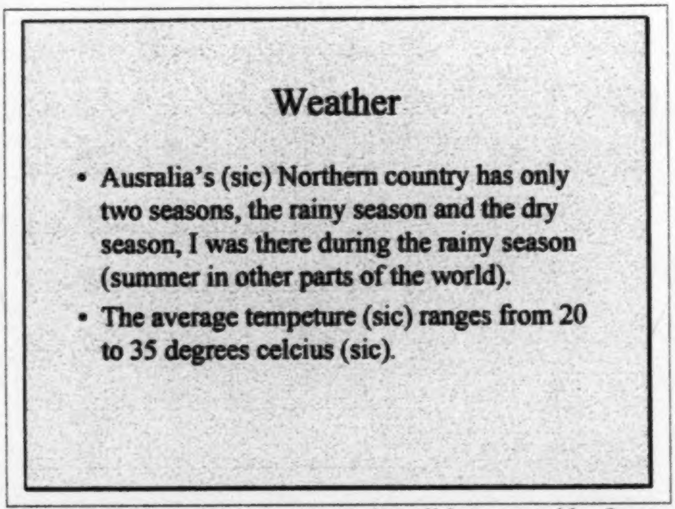
Expenses in Nepal

- Air travel = approximately $2360.16 for a round trip
- Hotel Menang, Kathmandu (discounted) $43.82 per day
- $1-2 for breakfast, $2-3 for lunch, and $3-5 for dinner US.(about $78.88 total)
- Extra day food and lodging $14.61
- Chitwan National Park 2-day permit $18.99
- Guided canoe trip/jungle walk $ 7.30
- Food $21.91
  - Soup $0.73
  - Pizza $2.92 - 5.84
  - Cake $1.46 - 4.38
  - Bottled water (liter) $2.92 - 5.84
- Total about=$2808.59
- With souvenirs maybe $3000
- http://www.vic.com/nepal/expenses.html

$ Prices in Australia $

- Gagudju Crocodile Hotel 250 kilometers east of Darwin. $154 per night. $1078 total
- I bought $200 worth of Old Dutch potato chips until I won a trip to Australia
- $722 left over for souvenirs
- A Visa is not required unless you (sic) stay s for a long time.

[illegible]



Weather

- Ausralia's (sic) Northern country has only two seasons, the rainy season and the dry season, I was there during the rainy season (summer in other parts of the world).
- The average tempeture (sic) ranges from 20 to 35 degrees celcius (sic).

Figure 13. PowerPoint presentation slides created by Jason.

Jason's attention to detail and his imagination are reflected in his PowerPoint activity in which he elaborated many of the details required for his PowerPoint presentation. He demonstrated the necessary exchange rate calculations and had made choices of what to visit in Nepal and how long to spend in the various areas of Nepal.

Jeff and Martin: San Francisco

Jeff is, as Dave describes him, a class clown. He engages in off-task behaviors quite regularly; he talks to students around him. Jeff is always quick with a joke or an antic that draws the students' attention toward himself, especially when he thinks, "The teacher isn't looking." Apart from school friendships, Jeff spends his free time in the company of his peers. He indicated that, although he had no computer of his own, he spent evenings at friends' houses playing computer games or on the Internet. Jeff is also an avid reader of fiction novels. He indicated, "In my future job, I won't need to figure out those formulas a whole lot so maybe just the bills. I want to write – freelance and creative writing." Jeff is also involved with school sports and skate boarding.

Jeff and Martin opted to work on the final project together. They both indicated that the PowerPoint activity was the most fun because they enjoyed looking for information on the Internet and looking at different places to go and visit. Both indicated that they had difficulties organizing themselves at the onset of the activity. In their

PowerPoint project (Figure 14), there was little more than the superficial included. They had not completed a large portion of the assigned work. When questioned in class as to how he and Martin were progressing with the activity, Jeff responded:

> Mary-Lee: So, Jeff, what have you been doing?
> Jeff: I've been working on my PowerPoint presentation.
> Mary-Lee: And what have you done so far?
> Jeff: Right now I'm just, like, all, doing all of the technical stuff, like all of the fancy stuff that you have to do to make it look good.
> Mary-Lee: Have you gotten all of the rest of the stuff done up?
> Jeff: Pretty much, all of our reservations for buses, hotels, so yeah.

Martin responded to the same question with the following answer: "I've found information for how much the plane tickets cost and hotel reservations." Somehow, either due to a technological failure or a failure to communicate between both parties involved with this activity, the end result (Figure 14) does not reflect what the students said they had completed. When the students were asked to present their PowerPoint presentation, they indicated that they were not finished and would need extra time to complete the work. Due to time restraints, I was not able to return to see the presentation but was sent what was completed by the end of the school year.

Jeff was missing at least one component from each of the first two activities and did not start the third optional activity. Jeff was quite adept at using the computer to, as he once indicated, "put in pictures and do neat stuff with the graphics. Right now I'm just, like, all, doing all of the technical stuff, like all of the fancy stuff that you have to do to make it look good." Dave agreed that Jeff spent an exorbitant amount of time "putting glitzy things into his computer activities and, consequently, did not complete all the work as was expected."

Jeff responded positively to both the pre-test and post-test *Fennema-Sherman Scales* regarding confidence towards mathematics. However, when I asked Jeff to comment on strategies he used when he encountered problems in mathematics, he responded, "I don't know, just stop the assignment. Just do something else." When asked to identify the activity that gave him the most difficulty, Jeff answered, "I think that the hardest stuff that you had us do during the whole thing was finding out how much something costs in American or whatever country I might use." These two statements might attribute a reason to Jeff's not completing the first two activities involving exchange rates – he found them to be too difficult, therefore, he lacked either the motivation to complete them or the tasks were so difficult that he felt unable to attempt the work.

When asked to comment about any difficulties he was having with the project and what he had learned, Jeff commented, "Well, I find it pretty easy. It's (the projects) okay. It's just really easy for me because I have had so much experience. There really wasn't that much for me to learn. I've got a certain standard for my brain, and my brain doesn't go any higher than that so no, no, I haven't really learned a whole lot." Jeff did not ask more than a few questions of the teachers. I am still struggling with the mixed messages that I received from Jeff. In one instance, he seems to exude confidence but in an other, especially when looking at his completed work, there is a lack of congruency. Perhaps it is that Jeff believed himself to be computer literate and that he took his ability to manipulate graphics in PowerPoint as being able to use the computer to navigate successfully in other computer applications.

Jeff realized the possibilities of computers helping him complete mathematics problems and had a lot more confidence using computers at the end of the study. Jeff was asked to attribute reasons for the shift from "neither" responses to "agree" on the following statements: "When using a computer, generally I felt more secure about attempting mathematics;" and "When using computers, I have a lot of self-confidence when it comes to mathematics." There was a shift from "neither" to "strongly agree" on the following statements: "When using a computer, I am sure I could do advanced work in mathematics; When using a computer I am sure I can learn mathematics;" and "When using a computer in the mathematics classroom, I am still doing mathematics." Finally, reflecting the shift from "disagree" to "agree" on the statement: "When using a computer in the mathematics classroom, I feel as though I am the person who is in control of the answers the computer gives me," Jeff responded, "Before you came, I never really used computers for math a whole lot. So Excel wasn't one of my big interests. I just used computers for word processing and entertainment but, after you taught us the formulas and stuff like that, it's easier now."

During the first three activities, Martin worked alone and seemed to be quite hesitant to ask me questions. Up until the second half of the project, Martin always asked

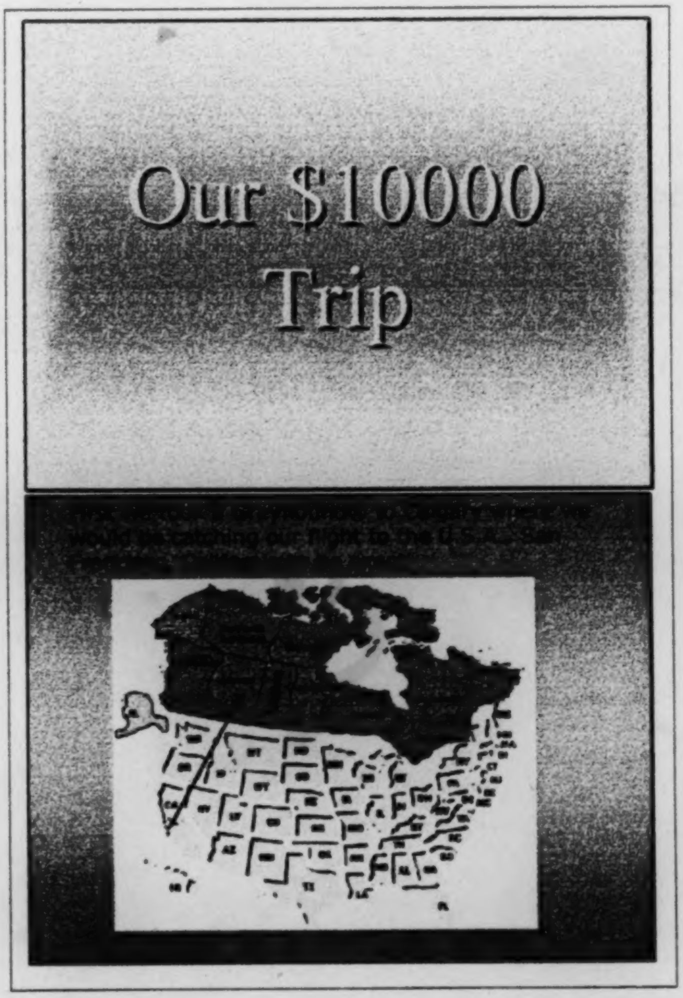
Dave or Corrine for help. The first time that Martin asked me for help was the day that Dave was away from the classroom. After that time, Martin would quite readily ask me for help although he never did require a great deal of additional assistance.

Dave described Martin as a "loner" and that he found him to be "quite bright." Mathematics is one of Martin's favorite subjects in school. During his free time, Martin likes to read books and play computer games.

Martin had worked consistently during the first three activities and completed all of them in full. He demonstrated perseverance throughout the study; after completing the first activity, his file was deleted. Consequently, Martin had to start the activity again. The same was true of his second assignment. Martin did not remonstrate regarding having to do the work over again, he simply stated, "Sometimes computers do strange things, and you lose all of your stuff. I don't mind doing it again cause I remember most of it anyway." It seems as though, unlike the other three students previously discussed in this chapter, Martin almost thinks of the computer as a "storage box," as something where information can be stored and retrieved. Margot stated, "I could always look back at what I had entered into the computer for my other assignments if I got stuck calculating stuff for the exchanges and that for the PowerPoint assignment." This is much the same view of the computer that Martin had in that it helped him organize how to proceed.

When I asked Martin why he persevered and completed the first three activites, he commented that the motivation for him was that "it's for marks so I want to do my best." Martin completed most of his work with little teacher interaction. Martin also felt confident in his abilities towards mathematics but attributed his slight change toward a more negative attitude regarding his confidence in mathematics as recorded during the post-test as he indicated, "This year, math hasn't been my best subject. When we started, I was doing pretty good, and then I had this one test that I got really bad on so I kind of went down a little bit."

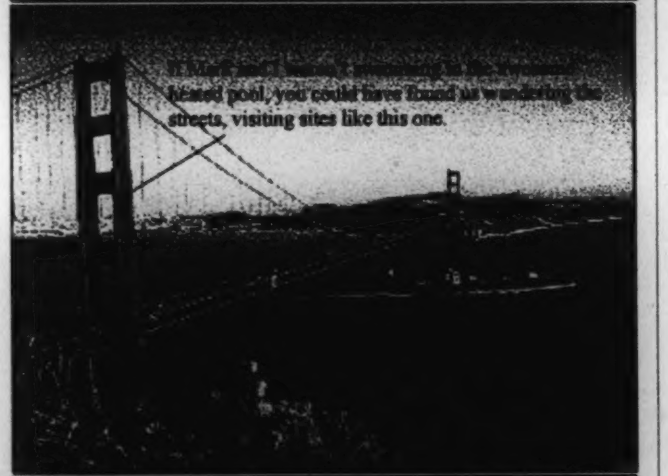
Martin showed a slight positive change in his attitude regarding his confidence in using computers to do mathematics from the pre-test to the post-test. Specifically, Martin felt more secure about attempting mathematics; he agreed that he could do more advanced and grade level work in mathematics while using a computer; and, believed himself to still be doing mathematics even though he was using a computer. Martin indicated that he preferred "the computers 'cause it's kind of easier because you just write out that formula," he indicated his frustration with using the computer in stating, "If you press the wrong button, it might all be gone so there's also, in a way the writing is easier."



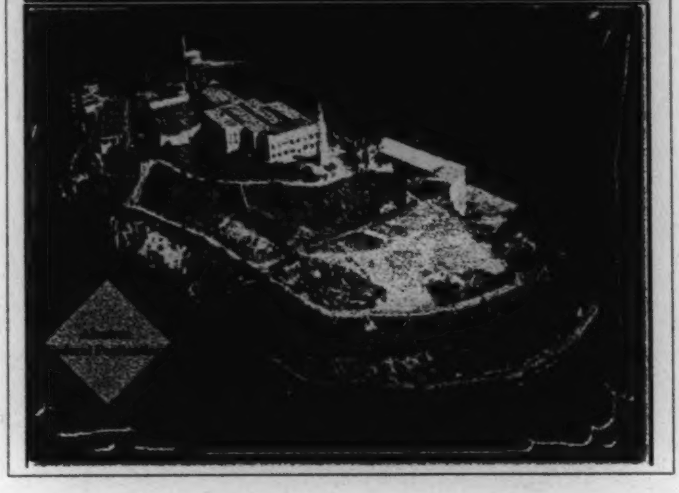
Our $10000 Trip

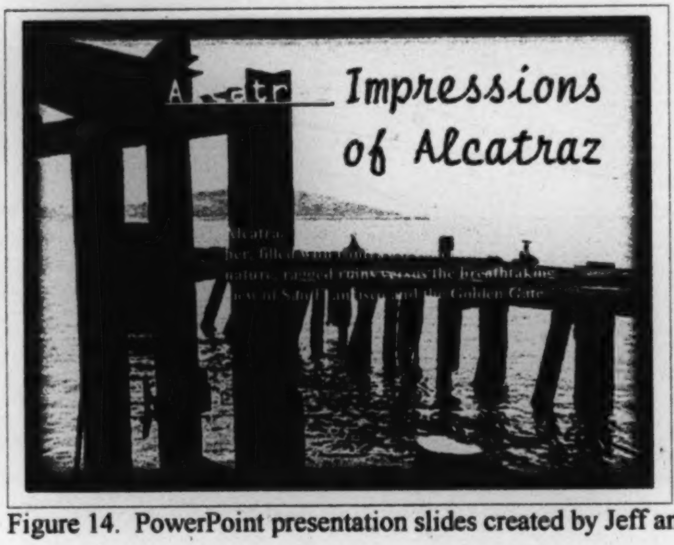
[illegible]
would be catching our flight to the U.S.A. San

We stayed at the luxurious Grant Plaza Hotel



[illegible] heated pool, you could have found us wandering the streets, visiting sites like this one.





Impressions of Alcatraz

Figure 14. PowerPoint presentation slides created by Jeff and Martin.

Jeff and Martin's PowerPoint presentation (Figure 14) was still in its plenary stage. At the time that the presentations were done, they had selected a place to visit but they were unable to locate the cost of items.

Interpreting the Statistics

The data obtained from the *Fennema-Sherman Scales* was analyzed using a *z*-score. A *z*-score analysis was used because when scores are transformed into *z*-scores, they can be compared on a standard basis. The *z*-score transformation is especially useful when seeking to compare the relative standings of items from distributions with different means and/or different standard deviations. "In every normal distribution, the distance between the mean and a given *z*-score cuts off a fixed proportion of the total area under the curve. Statisticians have provided us with tables indicating the value of these proportions for each possible *z*-score" (http://www.animatedsoftware.com/statglos/sgzscore.htm). Statistical tests are especially useful when trying to detect differences between populations or, as in the case of this study, changes within a given population.

Even though no significant statistical difference was found at a .05 confidence level for statistical significance for any of the items included in the pre-test or post-test, there are five statements that showed differences that invite further investigation. Of the five statements that I will explore in this chapter, four fell under the "Confidence Learning Mathematics with Computers Scale," and one statement arose from the "Usefulness of Mathematics Scale." Two of the statements are the positive statement and its negative counterpart and, thus, are dealt with under the same heading.

"Mathematics will not be important to me in my life's work"

The statement "Mathematics will not be important to me in my life's work" revealed a slightly negative shift for the study group as a whole. That is, they agreed with the statement more strongly after the instructional unit than before. While this is not a large amount of change, I felt that I should investigate reasons as to the decline in the *z*-score to this particular statement. The responses to the statement that attempted to assess the students' beliefs about the role mathematics will play in their future work indicated that students had a *z*-score of –0.3154 and does substantiate the change in the positive statement.

Some of the statements students made during the course of the study and during the follow-up interviews illuminate the noted change. Several students, such as Martin, felt that math was easier when using a computer because "you don't have to do all of the work. The computer does it for you." Rodriquez reiterated Manny's feelings when he indicated, "You don't have to do anything." Annie added, "You don't have to add or subtract or anything." Conversely, Jason thought that using a computer for mathematics was "too easy" because "You don't have to use a calculator or punch in all the numbers; you just have to enter the formula once."

My interpretation of what students said regarding the use of computers making mathematics easier leads me to believe that they might have felt that they had little ownership of the mathematics in which they were engaged while they completed the activities. I have a feeling that students might believe that, if the computer can do the mathematics correctly without any need for them to justify the answers arrived at by the computer, a student may lose confidence when using a computer to do mathematics. If the computer is viewed as the "thing" that "did" the mathematics for the student, the students may have changed their views regarding the importance of mathematics in their future. Many students indicated that they had no clue as to how the computer arrived at the answers it produced, and those students also agreed that the computer calculated the correct answer, regardless of the student checking whether the answer was correct or not. If students continue to view the computer as the producer of correct mathematical computations whatever information is entered into them, then it stands to reason that they view the usefulness of mathematics in their future as quite limited.

"When using a computer, generally I feel secure about mathematics"

The *z*-score for the statement "When using a computer, generally I feel secure about mathematics" was 0.4604. The *z*-score for its negative complement ("When using computers I am no good at mathematics") was 0.6617. Both the negative and positive statements reflect movement of the students' attitudes towards feeling more secure when doing mathematics with technology.

Students such as Manny, Lorne, Allan and Aurora saw that completing mathematics using a computer "was fun when it is easier." These students stated that they believed that, if they were able to complete the work faster, it was "more fun." Manny stated that computers "make it (mathematics) more fun because you can talk to your friends, and that helps me do better." Other students, such as Jeff, commented on his change of attitude towards using computers to complete mathematics problems: "It's like computers (make it easier) 'cause, like, before you came, I never really used computers for math a whole lot so Excel wasn't one of my big interests. I just used computers for word processing and entertainment but after you taught us the formulas and stuff like that, it's easier now."

While students might feel as though the computer enables their learning of mathematics, one must not forget that students felt that the computer did the calculations for them and that they had little to no control of the answers generated. Some students stated that they did not like using a computer for mathematics because, as Allan declared, "I don't like the formulas, and when you use a spreadsheet, you have to remember the formulas." Kate agreed with Allan in that "it was too hard having to remember all of the formulas." Denise had the same view of the formulas but also added, "I don't like the formulas. They are really hard to understand."

Some students who viewed the use of the computer as being fun equated the use of the computer in mathematics as easier. As shown in the above paragraph, some students saw the computer as an object that required them to learn a host of new formulas – ones they were not sure they were using properly. This may have had bearing on the students' views of using computers in mathematics.

"When using a computer in the mathematics classroom, I feel as though I am playing and wasting time"

Responses to the statement, "When using a computer in the mathematics classroom, I feel as though I am playing and wasting time," showed a slightly negative shift from the pre-test to the post-test. Upon reflecting on the statement itself readers may look at the aspect of "fun" that the students indicated they had experienced while engaged in the project. One might easily be lead to summarize that students who feel as though they are "playing" in the classroom may be doing just that. I argue that, at the initial onset, this is a valid student outcome because, as Bruner (1996) posits, there must be interaction between the learner and learning experience that gives one the feeling of wanting to become unstuck. Playing, I argue, affords the possibilities for students to become unstuck. It has been well documented that early childhood experiences are shaped by play. Why is it viewed by some that, at the introductory level to new experiences, students should not encouraged to "play at learning" before the formal instruction begins? In many ways, students who have computers at home already do this. They do not sit down with a computer manual beside the keyboard in order to "learn how to use the computer" – some adults will do this; junior high students will not. As shown in this study, they will try to answer the question on their own, or they will ask for assistance. Returning to Dave's anti-manual comment from Chapter IV, I believe that his comment:

> It is interesting to me, that in this whole technological process that the kids have become "anti-manual." You know how when you get a computer and they give you this great big manual and nobody reads it? I think that the kids have picked up on that. They learn by experience, or they want to learn by somebody tutoring them. They don't want to read the instructions to find out what it is that they are supposed to do.

is worthy of further interpretation. I have concerns regarding Dave's statement that teachers might expect students to automatically go to a manual or pull down the "Help File" from the toolbar. I believe that it is only after students have had a great deal of experience with the medium that they are willing, or have the ability, to do so. I do not believe that students will try to get unstuck by going to a manual or a pull down menu. On the contrary, I observed students asking the teacher and each other for help. I also observed other students attempting to try a different strategy as well as others who continued to repeat the same process over again. It is after the "initialization period" that students become more familiar with the terms they are seeking when searching for information.

I argue that students need to have an initial familiarity with what is presented in class before they are expected to find their own answers. To illustrate this point, I will draw upon the scenario of a student being asked to do a research project in a social studies classroom. The students are introduced to the subject and will spend a great deal of time learning about issues surrounding the subject before being asked to conduct an individual search in the subject area. The teacher may wish to use class readings, films, discussion groups or the like before the students are expected to commence working on an individual basis. It is through processes that involve story building and constructing a narrative, as Bruner (1996) suggests, that student learning is enabled. These initial steps, I argue, are the "play" types of activities that students engage in so that they become familiar with what they are expected to do as a final outcome. Perhaps the answers to my question only demonstrated my naive thoughts regarding introducing computers into the classroom. Students need time to explore the possibilities before being asked to work within the parameters that a teacher sets up. I do not feel that students were given adequate time, and I feel that I had lost sight of this knowledge while I was researching. We cannot expect to place students into the middle of a learning situation and watch them learn within the confines of a curriculum that must be covered within a certain timeline. This was the folly, I believe, of the spreadsheet activities. I had wanted the students to use the spreadsheet as a space to explore new possibilities for mathematics. Because the students did not have enough background knowledge, they were not able to adequately shape their own experiences within the period of time allotted to complete the spreadsheet activity.

The Four *Fennema-Sherman Scales*

Instruction of any kind cannot adequately respond to the needs of all students within a given time frame. The intended outcomes are not always what students learn as the result of instruction. Time is the crucial factor that influences all change, be it within the classroom context, curriculum, or students' attitudes and feelings of self-efficacy. In what follows, I will discuss the individual *Fennema-Sherman Scales* used in this study as well as general student comments and their pre-test and post-test results refering to each scale.

Confidence in Learning Mathematics

Generally, students' attitudes towards confidence in learning mathematics did not change. Annie indicated in her final reflection that:

> I find math about the same as I did before, but I have a little more confidence about myself doing math. I find math also a bit easier because of the formulas but also a bit harder because you have to memorize the formulas in order to use them. When I am doing math on a computer, it is the same as doing it without so it makes me feel less frustrated, but also it is something I have never done before so it makes me more frustrated.

Although Annie states that she felt more self-confident about math at the end of the project, her answers on the *Fennema-Sherman Scales* did not reflect her thoughts. Perhaps the answer to that discrepancy lies in her follow-up answer to the questions as to why the change might have occurred. Annie answered, "Math on a computer is a bit easier but also a bit harder so it is kind of like learning math again, and that isn't very fun, but that doesn't make me want to give it up." Another student, Kristy, indicated her feelings to me regarding the same dilemma: "It's like trying to learn to add and subtract all over again." I imagine that students in grade eight would have their confidence in mathematics shaken if they had to return to work they had been first introduced to in grade one and were now expected to look at through a different lens.

Kate wrote that she found using the computer to do mathematics "less frustrating because it gives me the feeling that I can do the work and do it easily. It takes stress off my mind knowing that I can do it." Kate added in the final interview that computers made her feel as though she wanted "to try harder at math because, like I said, it makes me feel good about myself, and I know that I am able to work through a problem easier and faster. This also makes me try more difficult questions or problems on my own and not asking some one because my self-esteem is higher, and I know I can find a solution."

Although Allan did not truly believe his attitudes towards math had changed as shown in his comment, "I feel the same as I always did in math," upon further discussion with him, he conceded that, "Some of my feelings have changed; like, the ones that have changed are I don't hate math as much as I did before. This is probably the funnest math activity I have ever done."

The Usefulness of Mathematics

Students' attitudes towards the usefulness of technology shifted slightly to the negative from the pre-test and post-test. Specifically, seven students demonstrated a significant statistical change in the area of the usefulness of mathematics in their future lives. Of the seven students, five indicated a negative change and two a positive change. Of the students who demonstrated a negative change, I have chosen to discount one student's comments. That student, when asked why all but two of the responses to the pre-test usefulness of mathematics question were in the agree column, answered, "I remember, I remember going, like, going down and doing them all in a row." When asked why, the student responded, "To get it done."

Lorne, Jakeb, Destiny and Allan are the four remaining students whom I have chosen to further investigate. As noted, a number of students commented that they did not see themselves as having control over what the computer calculated for answers. Allan, states "The computer kind of did it (the work) for us. We typed in some stuff and they (the computer) found out the answer." Using reasoning such as that presented by Allan, some students might be led to believe that computers are the way of the future for mathematics (seeing as the computer does all the work). If this is the case, students might feel that they have no ownership of the mathematics taught and that, no matter what they do, the correct answer is always "mysteriously" calculated. I argue that a scenario such as the one described above may have impacted on students regarding mathematics as less useful in their future. How could mathematics be useful when a machine can produce the correct answer at the push of a few buttons? This is a question that I should have asked the students at the time of the final interviews, but it was not posed to them.

When I asked Jason to comment upon changes he had seen in this scale, he was unable to pinpoint reasons as to why the change occurred. The following is an excerpt of the conversation regarding changes he perceived in the area of the usefulness of mathematics in his future:

> Jason: Mathematics will be important to me in my life's work and stuff.
> Mary-Lee: Now what do you think?
> Jason: Well, it went from neither to disagree.
> Mary-Lee: Yeah, so how come that happened?
> Josh: I don't know.
> Mary-Lee: Was that a result of the activities that you did in the class?
> Jason: I think so, perhaps.

Effectance Motivation

There was only a very slight change in students' attitudes in the area of effectance motivation. Jason showed a positive change, and he attributed the shift to his "liking puzzles" and "figuring out stuff, like, when we get a test back, I always figure out my percentages myself." Jason indicated that he really enjoyed working on such things as the PowerPoint presentation because he enjoyed "trying to figure out where I can go on just $5 000." To Jason, it seems as though this became a personal challenge and, thus, a motivating factor for him. What would Jason's view have been had there not been a PowerPoint presentation as the culminating activity? It almost seems as though the activity became the carrot on the end of the stick for several students in this class.

Confidence Using the Computers for Mathematics

The scale that demonstrated the greatest positive shifts in students' attitudes was the scale that tested students' views of their confidence in using computers to do mathematics. While most students did shift toward the positive, a few shifted toward the negative.

Nathalie had been struggling with using the computer during the entire project. Although she may have become discouraged, she continued to work through the activities. Even when a student "hacked" into her files and changed a large portion of the data, she re-did the assignment, laughing off the incident at the time. During the final interview, Nathalie mentioned that "somebody deleted half of my project so then I had to go back and try to find it," thus making the spreadsheet activity one of the hardest she had completed. In her final response journal, Nathalie wrote the following:

> I get more frustrated (when using the computer to do mathematics) because it's different than normal math in a normal math class. I've never been good at math, but when I'm in class, I feel I have more time to think about the questions I don't get. When I'm in the computer lab, I feel rushed, and I don't take as much time to think about things like I normally would. When I'm working on a computer, I am easily distracted because, when I'm on the computer, I'm usually thinking about adding some information to some stories that I write, and I'm not thinking about what I'm supposed to be doing.

Nathalie added that, when doing mathematics with a computer, she found herself wanting "to give up sooner because math frustrates me and because I am so easily distracted with other assignments and programs. I don't want to try harder because I don't think I can." According to Bruner (1996), cognition takes place through the apparatus we have in hand. Obviously, Nathalie did not have a sense of the computer being a tool that was available or "at hand." For Bruner, computer literacy is not the result of discrete skills that exist in the mind. It is, I argue, an architecture.

From my perspective, Nathalie struggled using the computer during this project. She was unable to make connections between what she was expected to do and how to accomplish the task. Although Nathalie showed extreme perseverance in her attempt to complete the work, she did not enjoy it. Coupling her dislike for mathematics with her dislike of the computer, I wonder why she did not act out her displeasure in class. When asked what she did when unable to answer a question, Nathalie answered that she became "frustrated" and that she felt like "killing the computer." Rather than going to such drastic measures, Nathalie indicated that she "just kind of got mad, and then I kind of got over it and then went back and started from scratch."

Martin, Paula, Josh and Kate seemed to get stronger in their confidence in using the computer for mathematics. In his final reflections, Martin wrote

> If we had computers in math classes, it would be a way too easy, and we wouldn't learn anything. I think that I try as hard as I can in math anyways. I have been trying harder now already because I have been having some troubles in some of my projects. Math on the computer hasn't changed me a lot but I think that it helped to never quit, and I've learned a lot off of this tech assignment.

Paula responded that when she used a computer for completing mathematics, "I tried harder when the math became harder, but I will always try hard." Josh commented that, "To me, math so far, whether by computer or by hand, is still pretty basic. I just never knew that you could do math with a computer." During the final interviews, Kate mentioned that she thought her scores had changed because "I never knew that you could do math on a computer. We always just use computer for stuff like PowerPoint and for writing stories." For Kate, the computer opened up new (micro)worlds for learning (Leron & Hazzan, 1997). By expanding the horizons of their computer worlds, students were able to move into new spaces where they could construct new meaning.

I believe that the reason for the change students underwent regarding their confidence in using the computer to complete a mathematics assignment was attributed in part to the students not knowing that there are applications on the computer that allow for mathematics investigation before instruction in this unit. I do not believe that students are convinced that computers are the best media to use for the instruction of mathematics. Many students indicated that they would much prefer to use paper and pencil so that they could "see their mistakes."

Summary

After reviewing the Fennema-Sherman Scales and then using them to pick up students' comments, there seem to remain several questions to be answered. Students who continue to see themselves as separate from the learning process when using computers in mathematics continue to be, for me, a major concern. Students were not asked if they view calculators as being the producers and suppliers of true answers; perhaps answers to this question may have indicated how to deal with the one raised above.

The issue of students regarding work that they deem "easier" as "more fun" is one that I feel needs further investigation. Do students envision themselves as engaged in school work if they are working in school even if the task is an easy one that they are able to accomplish? What are the implications of this type of reasoning upon pedagogical practices? This brings to the forefront the aspect of play. From Bruner (1996) we learn to become "unstuck" by learning to solve the problem not by internalizing procedures. The students become engaged learners through play. Thus, they are able to create cognitive maps of the world which, as Clinchy (1995) suggests, allows students to create cognitive diagrams that are similar to world maps.

I argue that students in this study were placed in the situation of going on a journey, thus giving them a space in which to create their own cognitive maps of the world. The intention was to give the students space to explore but, due to the rigidity of the spreadsheet and database activities, the micro-world that I had planned to use became little more than one of filling out cells on a spreadsheet. This limited their exploration and proceduralized it. The PowerPoint project, on the other hand, allowed students the freedom to explore. This point is evoked by what the students presented in their PowerPoint presentations.

The outcome of maintaining control over the students' moves and "intellectual authority" (Jonassen, 1996, p. 266) with creating the spreadsheet and database activities demonstrated that there was little authority relinquished to the students. The authority was only shifted to the students when they began the PowerPoint activity although Dave and I maintained the right to assessment. Thus another dilemma is created with respect to decisions classroom teachers make with regards to allowing students to explore areas with which they are already familiar while needing to control instruction in areas that are new to students. There must be a balance struck between introducing new concepts and allowing students time to "play" in these new situations.

I realize that what Vosniadou (1996) argues regarding constructivism has been accomplished through the PowerPoint activity. Students were given an activity that "facilitated social and cultural interaction" (p. 95) in that the students were permitted to work with other students and ask other students for help or even ideas for the PowerPoint presentations. As the students worked together, they had to negotiate choices with themselves and their partners while respecting the money allotted for travel – a cultural constraint.

VI. CONCLUSION: IMPLICATIONS FOR TEACHING AND FURTHER RESEARCH

Introduction

The purpose of this study was to identify whether or not computer activities contribute to shifts in student attitudes about mathematics. In order to answer this question, students were administered parts of the *Fennema-Sherman Mathematics Attitudes Scales: Instruments Designed to Measure Attitudes Toward the Learning of Mathematics by Females and Males* and were interviewed to identify specific activities that engaged them in the most significant ways. Specifically, the study asked students to reflect on changes in their attitudes following a series of activities where they used computers as, to use Jonassen's (1996) term, "mindtools." Students completed two spreadsheet activities, one database activity and one PowerPoint activity during this study.

Can Mathematics Really Be Easy?: Students' Perceptions

In the final interviews, I found that the students' attitudes and their feelings of self-efficacy were more positively affected by the fact that they were engaged in what they perceived to be an "easier" mathematics unit both in the regular classroom and in the computer laboratory. Some students explained that, since they were obtaining higher marks in class than at the onset of the study, they had a more positive view towards mathematics. Other students, such as Jason, stated, "I really like math, and I'm getting better at it." When asked if the computer activities might have helped, Jason answered, "I don't know, perhaps. That could also be because we moved to an easier unit."

Other students, such as Aurora, disliked using the computer for completing mathematics and she indicated that she "didn't like any of the project." She and other students found the activities to be too hard for them. Astrid indicated that she disliked computers intensely and really saw them as "useless." Even though Astrid has a computer at home, she never spends any time playing games on the computer or searching on the Internet because she feels that computers were "useless and a waste of time."

For Amelia, Rick, Lorne, Manny and Charlotte, "easier" in mathematics meant that work was more fun. Amelia explained that, when things are easier for her, it is because, "It's kind of fun because you get to use the computers, and now I can do things that I couldn't do before." Rick explained that when things are fun, he just "wanted to do more of it." For Lorne and Manny, what a teacher does and how information is presented in class influences the way they view math. Both students began a joint discussion in the follow-up interview in which the following was said:

> Lorne: It's just the way that the teacher teaches it.
> Manny: Yeah.
> Lorne: If the teacher can makes it fun and easy...
> Manny: Or if the teacher makes it long and hard...and if you don't like the attitude of the teacher, you're not going to like the math. So if you don't like the teacher, you're not going to do good in the math.
> Lorne: Right, that's right.

Allan, Annie and Kate viewed "easier" as being the ability of the computer to complete the work for them. Mathematics became easier using a computer because, according to Allan, "You just typed in the equation and it would do it right for you. You didn't have to solve it or nothing. The computer kind of did it (the work) for us. We typed in some stuff, and they found out the answer." Annie responded in much the same way that Allan did. She stated, "Computers make it easier because of the little formulas, and they add it all together for you. Like, all you have to do is put in a formula, and you get an answer." While Kate agreed that the use of computers made mathematics easier, she also added, "The computer makes it easier, you just have to push, like, the cells so you don't really know what you are doing. You know that you are dividing, but you are not really getting the skills that, like, you're not always going to have a computer with you when you need it."

For some students the math became easier because of the process of familiarization with the tools being used. For others success resulted from the course content being seen as easier, thus allowing students to succeed. The marks of these students reflected that their marks had indeed improved. For the other students noted above, the question remains: "Why was the math easier?" The students did not realize that they were the ones who were doing the math. For these students, they were "escaping" the math. Perhaps these students were just "plugging in" numbers, and they had no clue about what was going on mathematically. Certainly, this must be the case for those students who viewed the computer as the "thing" responsible for "doing the math." I argue that the students' inability to understand what was occurring, mathematically, indicates that the activity became technology driven as there was for some students, a lack of connection made for the students between the micro world and their worlds.

The Teacher's Attitude

Although the study intended to focus on students' attitudes, the teacher in this study expressed a profound change in attitudes towards integrating mathematics into the classroom. Where the teacher was initially dubious as to the educational merit of using computers because of the amount of time involved in teaching students how to use the tools competently, the end result was that the teacher felt as though the experience had been a positive one for the students. Brooks and Brooks (1993), who conclude that teachers themselves must learn new skills in a constructivistic setting. It is within that setting that teachers can create educational visions that, in turn, allow for them to reflect upon their personal teaching practices. Dave realized that he could have spent more time preparing for the lessons that he taught and that he could have spent more time learning how to use the various applications in order to best fulfill the needs of the students. In Dave's mind, this was not a necessity as I was to be present when the students were participating in the activities. The situation that Dave and I found ourselves in during the course of the study was, I would argue, a constructivistic setting that allowed Dave to create his own meaning as the activities unfolded and also allowed him to reflect upon his own teaching practices.

Dave's dilemma remained in that he felt as though the students had "surpassed his capabilities very quickly." Teachers should accept the possibility that students might surpass the expertise of their teachers very quickly. Teachers must, therefore, continue to upgrade computer skills and accept that they cannot be the "knowers" of all knowledge.

The major reason, I believe, for the lack of expertise of the students using computers as mathematical tools is that, in previous years, teachers have not felt comfortable enough with providing access to a technological environment that can make students aware of the mathematical possibilities contained within the computer. The technology wave is new in the province of Alberta. Teachers need to hone their personal computer skills in order to apply all the possible benefits from their usage.

Dave indicated a "need to control the process." By "controlling the process," Dave meant that he was the person who was in charge of the classroom environment, what the students needed to learn and how this learning was to take place. In summation, Dave showed an instrumental approach to his teaching style that is resonated in the phrase of "controlling the process." By controlling the process, Dave indicated that he controlled the outcome. One needs to examine carefully how a teacher's beliefs influence those of their students. As Manny indicated, once the students were allowed to talk in class, the challenge became greater "like, if you're skate boarding some place alone, you don't have any friends to talk to or anything, it would be boring, you wouldn't perform very good, but when your friends are there, you can talk to them, and you can tell them what you are going to do. Using math in computers is the same when you get to talk. You get to show off what you know."

Control issues remained one of the major concerns for Dave throughout the initial part of this study. As the study progressed, he shifted the locus of control from himself to the students as can be seen in the following excerpts from his reflections. After our first session, Dave commented, "I need to control talk and topic." Following the third day, Dave noted, "I'm not totally obsessed about control and silence." Finally, Dave commented on day four, " My classroom can be noisy if that is what the activity requires them to do." Situated learning theories advocate that the context and the culture in which learning takes place have a major influence on the learning that takes place (Brown & Duguid (1994). It is both the "context and the culture which define it necessarily affect the kinds of learning that is engaged and fostered in it" (Carr, 1998 *et al.* p. 5). Learning is, therefore, entwined with the situation in which the student constructs knowledge. I argue that the control issues expressed by Dave had a deep impact upon how much students were willing to explore. In my view, students who are reliant upon a teacher for such things as directions and personal control are less likely to venture to explore and experiment on their own.

Williams and Baxter (1993) argue that students' affective investment in mathematics is determined by the different ways in which they make sense of the world of mathematics. For example, students who see mathematics as contributing to future careers are much more likely to tolerate ambiguity and different problem solving situations. Dave's concern for maintaining classroom control fails to recognize that the individual students' sense of autonomy variously enables and limits their mathematical performance, nor did it allow for students to always make connections of the mathematics they were manipulating within the activities to view other ways of making mathematical meaning. In a word, there is no one best way to manage either students or knowledge. Rather, we need to recognize the centrality of students' affective reactions to mathematics in ways that contribute to the "occasioning" of their learning (Kieren, 1995). Through such teaching strategies as listening to students' voices, students are able to articulate their learning and their actions even if the listening is done in an informal fashion. This process allows teachers to, in turn, "occasion" students to become engaged in mathematics (Kieren, 1995). Problems arose for Dave when he decided to take a lesser role in guiding the students and let them explore on their own. It was at this point that Dave took on the role of facilitator. The students soon were able to work on their own, but Dave was unsure of what to do in the classroom. He had taken the position of, as Carpenter and Fennema state (1992), looking "over-the-shoulder," which was an unfamiliar place for him in the classroom, and he became more willing to listen to the affective reactions of the students. Dave commented:

> What was interesting was the ebbs and flows. At times, there was almost absolute quiet and then a few people would whisper, and they kept looking, and then at other times you could see that they had to schedule in their own little artificial breaks. In a classroom, those artificial breaks are what destroy your learning environment. In this lab, those artificial breaks were something that was unconsciously scheduled, but they still decided that they were going to go back to the task. I think this says a lot about the challenge that they found or the intrinsic motivation that they began to find as they

> began to work through those things… I also noticed that students were talking about the activities themselves. It wasn't always about what they had to do; they were also talking about how the felt about the PowerPoint activity. It was really amazing. I had never really heard the students talk about the fun that they were having with the activities until they started in on the PowerPoint activity.

Teachers using technology in the mathematics classroom, or any classroom, should look at new approaches in learning. Such practices as asynchronous learning strategies are essential in order to accommodate all learning styles and rates of learning that may be found in one particular classroom.

Classroom Realities

During this study there was a lack of time for students to come to know how computer applications such as a spreadsheet function related to mathematics. Research suggests that "teaching takes place in time, learning takes place over time" (J. Mason, personal communication, June 6, 1999). Statements such as Mason's suggest that learning is a maturation process rather than a chronological process. Mason's conjecture parallels that of Immanuel Kant (1934) who averred that a sequence of experiences does not add up to an experience of the sequence (pp. 30-31). In other words, it is not enough to have had the experience; we have to work with the experience for learning to take place. Further support is sited in Carr *et al.* (1998) who believe that "knowledge is a product of activity, not a process of acquisition" (p. 6). My research presented here concurs with research conducted by others (Mason; Carr, 1998; Von Glasersfeld, 1997). It is not known how much time is needed for experiences to equate to knowing as the time frame is different for individual students.

Typically, we evaluate technology integration over the short term rather than the long term. According to Fullan (1997), you cannot force people to change, to think differently, nor to implement change. In order for change to occur, conditions must be created "that enable and press people to consider personal and shared visions and skills development through practice over time" (p. 37). Fullan suggests that the change cycle can take as long as eight years to occur, thus, I argue, reflecting the view of people as "life-long learners." Teachers and students need to learn how to function in a technological world. Fullan's reasoning is a subtle form of "technological rationalism" that uses institutional structures and agendas of scientific and institutional application with little regard for human intuition, cultural life and community values. Such a limited rationalism is a view of human reasoning that tries to make people fit change, not change fit people. The justification for this is, of course, that the institutional needs of a greater good are paramount – accepting change becomes necessary for "societal well-being" (Taylor, 1997, p. 27). Justifications of this sort neglect the impact of the affective domain on change and how the teachers themselves view the role of technology in the curriculum.

One way for teachers and students to adjust to operating in a technological world is to review such aspects of school cultures as scheduling. Schools should reviewed scheduling to allow for flexibility within the daily schedule. Rather than having a regimented timetable for computer laboratory usage, schools should look at other possibilities for scheduling so students can reap the best possible benefits of computer usage.

Instructional Design

In a recent article written by Bitner *et al* (1999), entitled *The Virtual Trip*, an activity involving students (grade six through to adults) planning for a trip is explained. Students were to plan a trip involving a five-day vacation. Money was no object and tour packages were not allowed. Students had to include at least one air flight in their plans. Students needed to include meals, accommodations, attractions to visit and any other information to round out the vacation. Sound and visual clips were also to be included in the final multi-media presentation. The database that was created included information they located on the web. A spreadsheet was used to calculate the cost of the trip and the average cost of expenses per day. This information was used to create two graphs dealing with daily expenses by day and expenses by activity type. There were two culminating activities, one of which involved students writing a 750 word creative story about their virtual trip using a word processor and imported pictures from the web. The second culminating activity involved students creating a twelve-slide multi-media presentation. Of the twelve slides, the following had to be included: two slides with clip art, two slides with WordArt, two slides with graphics from the web, two with sounds from PowerPoint, one with sounds from the web. In addition, students were to use various font sizes and colors for text, PowerPoint transitions and to build effects. Students had three slide to use at their own discretion.

While this activity is similar to the one used in this study, the conclusions arrived at are quite different, perhaps due in part to the one presented in my study focusing more on the mathematical component. Bitner *et al* (1999) concluded that only a small number of the students who completed this project did not enjoy what they had done and that only a few students had problems using the application. As with the students involved in my study, it was conveyed in the article that, if the problems were dealt with at the onset, further frustrations could be eliminated.

Although Bitner *et al.* (1999) make connections to the mathematics curriculum, there is no discussion of what the students learned mathematically nor in language arts, for that matter. The article concludes that "students (who) complete the exercise (are) better able to search the Web and with better understanding of how several applications can be used with one another, which shows the computer's power as a teaching and learning tool" (p. 9). I believe that, as educators, we had best look at where the computer can be integrated into the existing curriculum rather than treating it as an appendage that is "tacked on" rather than "tucked in." It is my belief, and perhaps bias, that by tacking on technology, educators are treating technology as a separate subject area and, therefore, are removing the possibility for technology to be used as a source of enablement in the classroom.

Thus, we move to the question regarding using technology in the classroom and doing bad things more brilliantly (Judah, 1999). Coombs (1995) raises the difficulty to which I am referring when he discusses the importance of cognitive scaffolding in designing and managing constructivistic learning situations. Coombs (1995) argues that students require mental structures with which to engage problems. The persistent dilemma remains for teachers like myself: how does one know when the scaffold becomes all that is accomplished in the classroom? For example, by repeatedly drawing on spreadsheets as a scaffold for students planning a trip, there is a distinct possibility that much of what enabled student learning was restricted only to the interiority of the spreadsheets themselves. In other words, when does the domain of the learning activity threaten the possibility of the students ever going beyond its boundaries?

Instructional design using technology has, as its call, the possibility of students re-representing knowledg,e thus enabling and enhancing learning. While it may be true that computers as mindtools could offer the possibility of reconstructing experience, there remains still the need to determine the transferability and application of mathematical capability in a variety of situations and circumstances. Even though my research did not concern itself with mathematics understanding, I remain ambivalent as to whether or not students achieved sufficient independence and understanding of the mathematical functions that were constructed out of experiences lived in the technology activities. My own hesitations resonate Vygotsky's (1978) sense that, for learning to have taken place, students must achieve a process of "becoming" where the "tool without" becomes the "tool within."

At times, students found the mathematics involved in the study to be easy, but they were unable to cognitively link what they were doing with their actual classroom mathematics. Students viewed the computer as the agent engaged in mathematical thinking rather than themselves as being efficacious agents. They felt that, as long as a formula was entered into the computer, they no longer were involved in either the process or the outcome. Students were regularly seen entering data and formulas, but never questioning the viability of an answer. Students were, therefore, misled into believing that the computer "makes" the correct decisions. I feel that this further contributed to the students' disassociation from the cognitive process that makes mathematics possible and develops their self-efficacy.

Even though students demonstrated no measurable change in their attitudes towards mathematics, they learned to complete assigned tasks in mathematics when using computers. At the onset, the students were very teacher dependent, to the point of my not being able to keep field notes and move from the role of researcher to reseacher-teacher. Even with two and three teachers in the room with a class of twenty-three students, there was no time to keep accurate notes as the teacher demand of the students was very high.

Throughout the course of the study, students became less teacher dependent and more willing to take risks as well as to attempt to solve their own problems as they arose. I believe this to be a positive change as the students became much more able to solve their own problems - a skill that is fundamental to mathematics. Perhaps if the students had been exposed to using spreadsheets and databases in the mathematics classroom before the onset of the study, they would have been able to use the computers with more ease and expertise. The result may have, in turn, allowed for the possibility that the students could concentrate more upon the mathematical concepts that were introduced via the computer. I base this assumption on two facts. Firstly, students who demonstrated the greatest change in the *Fennema-Sherman Scales* stated that the reasons why they felt more positive towards mathematics were due to currently receiving higher grades in mathematics than they did at the time of the pre-test. Secondly, the mathematics that they thought would be difficult was viewed to be quite easy because of the computer.

The computers, as indicated above, are a scaffold, but scaffold to what capacity? For example, in the article written by Bitner *et al.* (1999), the authors claim that students' ability to present information on a virtual trip is an indication of "the computer's power as a teaching and learning tool" (p. 9). However, it is clear from the author's description of the students' activities that the emphasis was on providing re-representations of information (using WordArt, PowerPoint, graphics imported from the web) rather than on students performing mathematical calculations and transferring mathematical understanding to new situations. A particularly poignant comment is when the authors extol the virtues of students who "experience multi-tasking as they import graph, charts, graphics, and sounds into the various application files" (p. 7). For me, activities such as *The Virtual Trip*, and the unit of instruction I used in this study, point to the problem that teachers face: is technology an end in itself in the classroom? Are we in danger of increasingly confusing students' ability to manipulate data with understanding the data? Are our classrooms in danger of becoming little more than an arena for electronic versions of show and tell?

The implication of the above questions in the regular classroom is that teachers need to invest a great deal of time into preliminary classroom technology integration prior to its use in the mathematics class. Teachers must have a clear idea of how technology should be used and why it is being used in a particular learning situation. It is through this type of technology integration that I believe that students will be much more able to make connections between what is taught in the traditional mathematics classroom and computer enhanced instruction. The intent of such intervention would be to assist students in viewing themselves as the knowledge builders while using the computer to solve problems.

Teaching Practices

Historically, mathematics researchers "tended to separate the learning from the understanding" (Kieran, 1994, p. 591). As well as this gap, we have separated the affective domain from much of our discussion about mathematics learning. The learning of mathematics was traditionally limited to analyzing understanding, the retention of facts and the transfer of learning to new situations. Understanding was, therefore, deemed to be judged as the learner's abilities to know information and apply what was learned to a new situation and the learners' ability to analyze information as it was presented (Kieran, 1994). This view is limited by the fact that it does not take into consideration the importance of the individual as a learner nor the need to reflect this fact in teaching practice.

The main goal of researching students' attitudes towards mathematics is the net result of assisting teachers to recognize possibilities for improving teaching practice as well as student learning. Therefore, a major question remains for me: How much mathematics learning is going on? Students were engaged in the activities, but they seemed to be limited in their ability to make mathematical meaning between what mathematics occurred within the spreadsheet and how that was transferable to mathematics they had learnt using a piece of paper and a pen. How did the lack of a link between these two realities affect students' attitudes and feelings of self-efficacy? A subsequent question also arises: Are teachers too concerned with immediate learning as opposed to long-term understanding? I believe that the answer to this question would have enormous implications regarding student attitudes. This querry brings into question whether or not teachers are being overly ambitious in the setting of goals for their students and whether or not teachers are expecting too much from their students by believing that a certain amount of learning should have occurred within a given time period? What, then, are the secondary effects of the situation upon students' attitudes and feeling of self-efficacy?

Appropriate Uses

Perhaps I need to search beyond the students for the answer to my question and look at the possibility that the spreadsheet can provide a rich environment that allows students to build meaning. Kant's (1934) and Mason's (personal communication, June 6, 1999) words regarding teaching versus learning resonate with the truth that students were only allotted the equivalent of two hundred twenty minutes to complete two spreadsheet activities. Students need time to manipulate and experiment in order for true learning to occur. I doubt that the time afforded this activity would have been sufficient for learning to occur for all students nor to suit all learning styles.

Thus the dilemma remains. Is the spreadsheet a place, a microworld, where students can hide from mathematics, or is it a place that enriches and, ultimately, enables mathematics? If the spreadsheet were a place where students can hide from the mathematics then, I would argue that the spreadsheet becomes its own little microworld within the larger micro-world of the Planning a Trip Project. If students are able to hide from the mathematics, how does this speak to changes in attitudes students might undergo when using a computer in the mathematics classroom? It is possible that the "Planning a Trip" activity may live in between the poles of a fantasy world and the real world. In another sense, as a microworld, it exists as an analogue of the real world. Von Glasersfeld (1997) states, "Cognition is not a means to acquire knowledge of an objective reality but serves the active organism in its adaptation to its experiential world." I believe that the activities used in this study acted as the catalyst that links the students' "experiential world" to the individual student's "objective reality."

Autonomous Learners versus Teacher Dependent Learners

Students whom I observed to be quite autonomous said they enjoyed the computer project more. Teachers should take this fact into consideration when designing programs that use technology in order to promote a greater sense of self-efficacy among the students. The students who are more autonomous will need to have means of giving feedback to the teacher as the teacher may spend more time with other students, and there is a chance that more autonomous students will receive less teacher input to their work. Such strategies such as one-to-one interviews would be useful so teachers can maintain contact with these students.

Students whom I observed to be more teacher dependent did not receive enough feedback from the computer in order to guide their own learning. These students were in need of continual teacher contact, which, in turn, removes the teacher from a large amount of what is occurring in the classroom around him. Students who fall into the category of needing a substantial amount of teacher help were more apt to give up more quickly, therefore demonstrating what Bandura (1982) would term as "creating a resistance in (their) operative capabilities," which results in a negative self-efficacy (p.421). There are two implications for the classroom teacher regarding this finding.

Firstly, teachers must have guidelines in place regarding proper computer laboratory usage and classroom discipline routines before allowing students to work in a computer room. If a teacher is unable to control students in a classroom setting, the underlying issues of classroom management will not be resolved just because students are placed behind a computer. I argue that, when a teacher's attention is diverted elsewhere, say to a teacher dependent student, there is the possibility for classroom discipline problems to become exacerbated.

Secondly, teachers may wish to consider using co-operative learning teams or pairs in the computer laboratory. As with all co-operative learning teams, the teacher should have the final say as to within which partnerships students are allowed to work. Teachers also must be aware of the problems and successes of students working in pairs before they undertake such an endeavor in their classrooms.

Critique of the Activity

This project undertook to examine how students' attitudes and senses of self-efficacy toward mathematics would be affected by computer use in the mathematics classroom. What was most surprising was that I had not expected the results that I observed in this project. I must admit that, when started my research, I had a definite desire for a set of anticipated outcomes even though I tried to bury these desires in order not to obtain false conclusions. I had anticipated that the students' attitudes towards mathematics and that their feelings of self-efficacy would have become more positive based on the merit of being able to use computers in order to explore mathematics. The *Fennema-Sherman Scales* showed slight changes in attitudes towards mathematics, but this shift was not statistically significant. This in no way diminishes the power of what took place within the context of the integrated computer activity. What was brought forward as the research project unfolded was a series of conversations and self-reflections that identified the powerful forces at work when students and teachers are in a process of "having a world" (Verela *et al*, 1991).

At the completion of the project, I wondered if I had created a false economy by doing too many activities in too little time. As discussed in this chapter, learning does not occur as a result of students being taught a concept. The learning process occurs over a longer period of time, and this might occur long after the concept has been taught. It is only through experience that students can learn. For these reasons, it would have been worthwhile to spend more time in the mathematics classroom itself and to be able to see more of the connections of classroom instruction to laboratory instruction and students functioning within both. The inordinate amount of time spent by students on the computer activities, without sufficient classroom time working with fellow students and the teacher, meant that there was limited feedback to help determine just how students were coming to know the material.

I argue for the need of an understanding of the teacher's role in the constructivistic sense of how cognition works: to be both facilitator and teacher who engages students in their own learning; to be a guide-at-the-side (Kieren, 1995). Drawing from Vygotsky, Crawford (1996) argues that the teachers' role is one of "providing support for action beyond the individual capacity" of students (p. 44). Being attuned to the assumptions, needs and purposes of students and being able to understand how students enact metaphors ought to be central to the mathematics classroom.

A key point emerged for me during the latter half of the study. Perhaps I had mistaken the students' engagement in creating spreadsheets as a mathematics activity. For example, Jeff commented about how his brain will only allow him to reach certain levels of learning. Does his self-concept limit his ability to use the computer beyond enhancing (Figure 1) his construction of knowledge as he, in his opinion, is not able to learn in ways that are not possible without the use of the computer? I am led to believe that it is students who view the computer as "storage boxes" (places to store their cultural artifacts for future reference) rather than the computer as the problem solver (the artifact that did the work for them) that are moving towards using the computer as an enabling tool.

Constructivism reminds us that it is important that we not draw a division between rational thought (strict one-to-one correspondences) and imagination (Tesch, 1990). This raises the questions of where is thought and where is imagination when students use computers as storage boxes. Could it be possible that it is the students' use of linking and grounding metaphors that allow them to move from using computers from enhancing to enabling learning? Grounding metaphors enhance "our understanding of arithmetic (which) rests on our intimate and precise understanding of domains like collecting, constructing, and moving... linking metaphors allow us to link one branch to another" (Lakoff & Núñez, 1997, p. 34), where grounding metaphors are ones which represent a way of getting "in the door," or as an enhancement, and the linking metaphors represent enablement, as a means of working your way into the core of mathematics and computers. We, as teachers, need to allow our students to learn relationally so those students can make their own metaphorical links. I am reminded of Bruner's dominant learning metaphor, one of a child put into a play: children may not know what the play is about, but through the process of engagement with the narratives available to them, they formulate "acts of meaning" that work for them (Bruner, 1990). We need to allow and encourage students to explore, and we need to let go of what we, as teachers, know so that we can explore old information in new ways in order to learn new things about old information.

Additional Factors

Although the sections described below were not the focus of my study, they did influence the classroom atmosphere and, therefore, have been included. I urge the reader to regard the following "side issues" as important influences that have a potential to affect the student's attitudes and feelings of self-efficacy.

Resources

The implementation of technology into schools comes at great cost. The dilemma raised by the cost of technology is not new to teachers or to their jurisdictions. Take, for example, the province of Alberta. Most schools were not in a monetary position to make such large purchases before the 1993 cutbacks.[5] What has changed since 1993, except that presently there are less funds available? In 1996/97, Alberta's expenditures in education had declined by 8.5% compared to 1986 levels (Statistics Canada Quarterly Reviews, 1996). What are teachers to make of the disparity between the government's stated goals and its lack of financial commitment to public education? Where are schools and school boards to access technological expertise and funds required to implement such programs? Will there be a reduction of professional teaching staff in order to make room for technical support staff?

Homework

As not all students involved in the study had computers at home, homework was not assigned. With increasingly technological school, how do teachers ensure that all students have equal opportunities to complete assignments? Does allowing students access to the computer laboratory for twenty minutes a day over the noon hour offer all students adequate access? Furthermore, what is the relationship between students' attitudes towards computers and computer access at home? For students who are unable to complete their work at school or for those that feel more comfortable studying at home, are there increased levels of frustration? Schools that have opted to have the computer laboratories open after school hours may not be addressing issues for students who, for example, live out of town and are bussed forty kilometres to school and forty kilometers home each day. I believe that this issue must be carefully examined.

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[5] As a job saving measure, the teachers in the province of Alberta agreed to take a five percent wage cut in the fall of 1993. It was not until 1999 that this rollback was recovered.

The Activity in Review: Building Microworlds of Possibility

At the onset, I had thought the activities used in this study would be sources of ways to enable students' learning and build their sense of self-efficacy as I felt that the students would be offered a learning situation in which they would be able to explore on their own rather than being led through teacher directed lessons that were prescriptive in nature. I believe that it takes time for teachers and students to move along the continuum from technology driven learning models to those that are focussed on ways students come to enhance their sense of efficacy through technology enabling activities. This project demonstrates both the pitfalls and promises of integrating technology into the classroom. Firstly, the students' lack of expertise in the area of technology was a major contributing factor as to why the activities were not enablers. Secondly, the integration into day-to-day learning activities represented a shift in the culture of the students and their school. As Jonassen (1996) argues, using computers as mindtools requires students and teachers to reorient themselves away from traditional classroom organizational practices. An obvious example of this shift was Dave's self-proclaimed need for control and monitoring of student progress. Thirdly, Dave's need to control learning situations did not lend itself to students exploring in ways that I thought possible. Dave's teaching style and my own are very different in several respects. The cultural shift I envisaged for the classroom was, in the end, my own. I must acknowledge and respect that, at the end of the day, these were Dave's students, and this was his classroom.

Despite all of these reservations, there were many ways that students were able to use the computers as mindtools. As chapters four and five illustrate, students generated several diverse and rich responses to the mathematical problems presented to them. Their projects and choice of PowerPoint presentations represented, for me, the culmination of their own journeys through a variety of microworlds. At a minimum, this thesis project was a rich beginning, a point of departure and not a final destination. I would argue, seen in another way, that the students' projects, in many cases, were about allowing learners to achieve what Bandura (1997) called the mastery experience. The mastery experience is the core of developing a student's sense of self-efficacy as they feel enabled to "organize and excite the course of action required to manage prospective situations" (Bandura, 1997, p. 2).

As I indicated earlier, student attitudes towards mathematics are determined by feelings of self-efficacy. Learning activities in mathematics classrooms that provide purposeful performance coupled with capacity building in problem solving (traditionally framed as the cognitive functions) will lead to the growth of student self-efficacy. Throughout the learning activities and follow-up interviews with students, I encountered what Bandura (1997) addresses in his work, that to focus primarily on problem-solving ability without attending to the affective domain of students' learning is a formula for disaster. To be continually confronted with seemingly insurmountable problems, to be subjected to rote memorization and drill, is to rob students both of self-efficacy and agency. As Bandura (1989) reminds us, "One cannot conjure up outcomes without giving thought to what one is doing and how well one is doing it" (p. 232). The students who feel they have little capability is never at a good starting point for learning. This was the case with Astrid, who indicated that she did not like using computers and that she felt that they were "stupid." Astrid never felt as though she had the capability to use the computer to do more than word processing. Even at the completion of the project, Astrid's view of computers had not altered. Despite views such as Astrid's, I believe that the learning activities I undertook with students afforded opportunities to build microworlds of possibilities. From these microworlds of possibilities flow agency and feelings of self-worth.

The teachers involved did indeed have an opportunity to implement new strategies into the classroom and to evaluate their effectiveness. Students were afforded opportunities to experience “having arrived” at particular places, at achieving a sense of efficacy and agency. Perhaps it is ironic that one of the greatest lessons drawn from having students participate in a virtual trip is that we took many journeys side by side. In this project, for both teachers and all the students, our sense of enablement and efficacy, our feelings about ourselves as human agents, derived from the journey itself and not from having arrived at a particular destination.

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Appendix A

Appendix A

Planning a Trip

Comparison of Exchange Rates

Activity One – Student Instructions

Sometimes when people travel, they have to stop and stay the night in a country other than their final destination. When this happens, people usually try to stay in that country for a few days and visit a few of the sights before flying on to the country of their destination. I was lucky to have seen London, England on my way to Turkey one summer. One other summer, I stopped in Hong Kong, on to Macao, then to Singapore before finally arriving in Indonesia. There are so many other countries that you can visit as well (Lonely Planet Guide) (Yahoo Travel Page). You are allowed to spend TWENTY-FIVE MINUTES finding and looking through one site. We are going to come back to these activities later in this mini unit.

When you travel to a foreign country, you need to exchange Canadian money for the currency that is used as legal tender in the country you are visiting.

In order to figure out the exchange rates between countries, you can visit sites such as The Foreign Currency Exchange Page. The first transaction to do is to convert CND (Canadian) to the country of your choice. On the *Foreign Currency Exchange Page*, select **Canadian Dollars** by clicking on it. Scroll down and hit the "Generate Currency Table" button. A comparison list of Canadian dollars to all countries in the database will come up on your screen.

Go to the spreadsheet, type the name of the country you will visit, and the exchange rate for Canadian dollars to the country you have selected. You then need to put in the appropriate formula for converting "x" number of Canadian dollars to any given country's currency. With this information, the necessary calculations are made to find out how much foreign currency you would have.

After this is completed, you are to put a journal entry into your math reflections about what you did in your spreadsheet. I would like you to focus on the formula that you used and how you arrived at that formula.

You will need to refer to the rubric in order to ensure that the spreadsheet is accurately completed.

Comparison of Exchange Rates

Spreadsheet Activity #1 Rubric

THE STUDENT	YES	NO
1. Has at least five countries listed in the spreadsheet.		
2. Uses an appropriate formula to calculate exchange.		
3. Applies the formula to a full column.		
4. Uses two different column widths.		
5. Uses two different font styles.		
6. Uses two different font sizes.		
7. Uses an alignment function.		
8. Uses the "fill" "function.		
9. Includes the following columns:	■	■
- Country		
- Exchange rate to the nearest 100th		
- "x" number of dollars		
- Amount of foreign currency received		
10. Sorts countries in ascending order.		
11. Writes a journal entry that includes:	■	■
- What processes were used.		
- What was done to get "unstuck."		
- How does the formula calculate.		

Mark for this assignment ______ /16

Planning a Trip

Buying Souvenirs

Activity Two – Student Instructions

Have you ever received a gift from someone who has been away on holidays? Usually, people bring back souvenirs for their family and close friends. In this activity, you are going to link into some on-line catalogues from different countries and select souvenirs from the catalogues. You need to select five countries from the list below and then calculate, using the spreadsheet, how much each souvenir will cost in Canadian dollars.

After you have finished this activity, your homework tonight is to find out how much the souvenirs would cost to purchase in Canada. You will need that information in order to finish the spreadsheet activity tomorrow. You can use the *Sears Catalogue*, flyers from stores, or call stores in order to find out the prices.

Australia

Bahamas

Egypt

England

France

Germany

Greece

Ireland

Italy

Italy 2

Jamaica

Japan

Netherlands

New Zealand

Scotland

Spain USA$

Switzerland

Planning a Trip

Buying Souvenirs

Spreadsheet Activity #2 Rubric:

THE STUDENT	YES	NO
1. Has at least five countries listed in the spreadsheet.		
2. Uses an appropriate formula to calculate the cost of the souvenir in Canadian currency.		
3. Uses an appropriate formula to calculate the difference in the price of the souvenir between Canadian currency and the country where the souvenir was purchased.		
4. Uses a "Cut" and "Paste" command.		
5. Completed assigned homework.		
6. Sorts countries in ascending order.		
7. Writes a journal entry that includes:		
➢ reflection about possible causes for changes in the cost of an item		
➢ a comparison of the cost of goods between Canada and one other country (Was the article more or less expensive in Canada?)		
➢ what formulas did you use?		
➢ what did the formulas do?		
➢ how was math changed for you while doing this activity?		
➢ submits the journal entry by e-mail (LJHS_GR8@hotmail.com)		
8. Participates in mini presentation.		

Mark for this assignment /13

Bonus Points: Include a graph of the "difference column," including labeling the X and Y axis. Include a description of the graph in your journal.

Planning a Trip

Organizing Information in a Database

Activity Three – Student Instructions

In the next activity, you will be asked to work on a database. The fields for data entry have already been established for you, but you will need to enter specific data into the records. For this task, you and a working partner will need to select five countries to visit, and you will need to find out how much one dollar Canadian is worth in each of those five countries. You then need to access ClarisWorks through the start icon on the bottom tool bar. You will need to open the document named, "Planning A Trip Template." Once this is completed, you will need to start entering your data. You need exchange rates, the year you want to travel, whether visas or passports are needed for travelling within that country, information regarding immunization and the answer to your calculation of the percentage difference of what you might buy for a souvenir. Don't forget to use the rubric.

Hotels

Africa

Australia

Arabia

Bahamas

Brazil

Caribbean

Egypt

England

Greece

Italy

Japan

Jamaica

Mexico

Seychelles

USA

Planning a Trip

Organizing Information in a Database

Spreadsheet Activity #3 Rubric:

THE STUDENT	YES	NO
1. Enters the country to be visited.		
2. Enters the exchange rate.		
3. Enters the date the exchange rate was recorded.		
4. Enters whether a visa or passport is required.		
5. Enters the year to travel to the country you have selected.		
6. Enters if an immunization vaccination is required or not.		
7. Correctly calculates percentage change in the cost of souvenirs in Canada and countries selected (1 point each).		
8. Includes calculated percentage in #7 as an entry.		
9. Sorts the data entered using the year you want to travel.		

Mark for this assignment /9

Planning a Trip

How I Spent $5 000

Activity Four – Student Instructions

You have returned from your trip and have had a wonderful time. Now you want to share your $5 000 adventure with your friends. You are to put together a PowerPoint presentation of no more than 10 slides that detail:

- Your name and your partner's
- The countries you visited.
- What you visited while you were there and the cost of admission.
- The exchange rates of each of the countries.
- How much you spent in each country (include meals, souvenirs, hotels).
- Some details about the interesting places you visited while in each country.
- Some photographs of each city (record the source).
- Any other details you wish to share from your trip.
- Complete all the rubrics at the end of activity four.

For the formatting of the presentation, you need to apply a design, use colour and use one form of slide transition.

Planning a Trip

How I Spent $5 000

PowerPoint Activity #4 Rubric: Teacher Evaluation

4	Consistently does all or almost all of the following: Accurately interprets data, statements, graphics, questions, etc. Identifies reasons (pro and con) to visit a country. Thoughtfully analyzes and evaluates major alternative points of view. Justifies key results and procedures and explains. Fair-mindedly follows where evidence and reasons lead.
3	Does most or many of the following: Accurately interprets data, statements, graphics, questions, etc. Identifies reasons (pro and con) to visit a country. Thoughtfully analyzes and evaluates major alternative points of view. Justifies key results and procedures and explains. Fair-mindedly follows where evidence and reasons lead.
2	Does most or many of the following: Misinterprets data, statements, graphics, questions, etc. Fails to identify strong, relevant reasons (pro and con) to visit a country. Ignores or superficially evaluates obvious alternative points of view. Justifies few results or procedures, seldom explains reasons. Regardless of the evidence or reasons, maintains or defends views based on self-interest or preconceptions.
1	Consistently does all or almost all of the following: Offers biased interpretations of data, statements, graphics, questions, etc. Fails to identify or hastily dismisses strong, relevant reasons (pro and con) to visit a country. Ignores or superficially evaluates obvious alternative points of view. Does not justify results or procedures nor explain reasons. Regardless of the evidence or reasons, maintains or defends views based on self-interest or preconceptions. Exhibits close-mindedness or hostility to reason.

Planning a Trip

How I Spent $5 000

PowerPoint Activity #4 Rubric: Peer Evaluation

The maximum points you can allot for any section is 5

1. Media = (Total Points: ________)

- Use of Resources: (sound, transitions, graphics, pictures, video)

Look at how the presenters combined the materials and used the variety of resources. Did they integrate into the presentation or seem "tacked on?" Is the quality of the resources an addition or a distraction to the presentation?

- Appropriate Technology:

Is this presentation benefiting from the use of this media, or would it just as well be done in another format?

---

2. Content = (Total Points: _______)

- Introduction

Was there a clear and evident introduction of the theme and content of the project? Is there an effective "grabbing" of the audience?

- Clarity

Is the content clear and effectively presented throughout the presentation? Do all parts of the project flow together and support the theme?

- Timing

Is there enough or too much time between slides for the viewer to read or observe the slide?

- Legibility

Is each image and lettering of size and clarity to effectively communicate?

---

3. Group Dynamics = (Total Points: ________)

- Sharing of Tasks
- Cooperative Decision Making
- Equal Work Load

---

4. Comments:

Planning a Trip

How I Spent $5 000

PowerPoint Activity #4 Rubric: Self-Evaluation

Give yourself a check mark for each of the following that applies to you and the way that you worked on this project.

Process:
5 POINTS
- ☐ Participates actively
- ☐ Models caring about goals
- ☐ Helps direct the group in setting goals
- ☐ Helps direct group in meeting goals
- ☐ Thoroughly completes assigned tasks

3 POINTS
- ☐ Participates in group
- ☐ Shows concern for goals
- ☐ Participates in goal setting
- ☐ Participates in meeting goals
- ☐ Completes assigned tasks

1 POINT
- ☐ Chooses not to participate
- ☐ Shows no concern for goals
- ☐ Impedes goal setting process
- ☐ Impedes group from meeting goals
- ☐ Does not complete assigned tasks

Communication:
5 POINTS
- ☐ Shares many ideas related to the goals
- ☐ Encourages all group members to share their ideas
- ☐ Listens attentively to others
- ☐ Empathetic to other people's feelings and ideas

3 POINTS

☐ Shares ideas when encouraged
☐ Allows sharing by all group members
☐ Listens to others
☐ Considers other people's feelings and ideas

1 POINT

☐ Discourages sharing
☐ Does not participate in group discussions
☐ Does not listen to others
☐ Inconsiderate of others

Interpersonal Skills:

5 POINTS

☐ Encourages group to evaluate how well they are working together
☐ Involves the whole group in problem-solving
☐ Actively participates in helping the group work together better

3 POINTS

☐ Participates in group evaluation
☐ Offers suggestions to solve problems
☐ Demonstrates effort to help the group work together

1 POINT

☐ Discourages evaluation of how well the group is working
☐ Chooses not to participate in problem-solving
☐ Promotes fragmentation of group

Appendix B

Appendix B

Computer Survey

1. Name_______________________

2. Do you have a computer at home? YES NO

3. How many hours a day do you usually use a computer?
Not at all Less than one hour 1-2 hours 2-3 hours 4-5 hours

4. We use a computer for many reasons. Think about your computer use during a regular week. Rank the following from 1 (most often) to 5 (least often).

_____ Games
_____ E-mail
_____ Internet
_____ Homework
_____ School work

During this project you have been using a computer to do math. Do you find doing math with a computer more frustrating or less frustrating? Explain.

Since you have been using a computer to do math, do you feel like you want to try harder at math, or do you want to give up sooner than in your regular math class? Explain.

Demographics

Sex	Computer at home	Hours a day spent on the computer
F	Yes	0
F	Yes	0
F	Yes	1
F	Yes	1
F	Yes	1
F	Yes	2
F	Yes	2
F	Yes	2
F	Yes	3
F	Yes	3
F	Yes	3
F	Yes	3
F	Yes	3
F	Yes	5
F	No	1
Total		30
Average hours using a computer/day		2.14
% of students with a computer at home		92.86%

M	Yes	0
M	Yes	1
M	Yes	1
M	Yes	2
M	Yes	2
M	Yes	3
M	Yes	5
M	No	1
M	No	3
Total		18
Average hours using a computer/day		2.00
% of students with a computer at home		77.78%

Appendix C

Appendix C

Directions
Fennema-Sherman Mathematics Attitude Scales

On the following pages is a series of statements. There are no right or wrong answers for these statements. The questions have been set up in a way which permits you to indicate how much you agree or disagree with the idea written. Suppose the statement is the following:

Example 1. I like mathematics.

Decide if you agree or disagree with the statement, and then decide how much you agree or disagree and place a check mark in the appropriate box. Your choices are:

Strongly Agree
Agree
Neither
Disagree
Strongly Disagree

Do the same for all of the statements in this booklet.

Do not spend much time thinking about each statement, **but be sure to answer every statement**.

There are no "right" or "wrong" answers. The only correct answers are those that are true for you. Whenever possible, let the things that have happened to you help you make a choice.

THE ANSWERS THAT YOU GIVE ARE BEING USED FOR RESEARCH PURPOSES ONLY, AND ONLY THE RESEARCHER WILL HAVE ACCESS TO THE ANSWERS YOU PROVIDE.

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Name: ______________________________

		Strongly agree	Agree	Neither	Disagree	Strongly Disagree
1	Generally, I have felt secure about attempting mathematics.					
2	I am sure I could do advanced work in mathematics.					
3	I am sure I can learn mathematics.					
4	I think that I could handle more difficult mathematics.					
5	I can get good grades in mathematics					
6	I have a lot of self-confidence when it comes to mathematics.					
7	I am no good in mathematics.					
8	I do not think I could do advanced mathematics.					
9	I am not the type to do well in mathematics.					
10	For some reason, even though I study, mathematics seems unusually hard for me.					
11	Most subjects I can handle OK, but I have a knack for flubbing up mathematics.					
12	Mathematics has been my worst subject.					

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		Strongly agree	Agree	Neither	Disagree	Strongly Disagree
1	I will need mathematics for my future work.					
2	I study mathematics because I know how useful it is.					
3	Knowing mathematics will help me earn a living.					
4	Mathematics is a worthwhile and necessary subject.					
5	I will need a firm mastery of mathematics for my future work.					
6	I will use mathematics in many ways as an adult.					
7	Mathematics is of no relevance to my life.					
8	Mathematics will not be important to me in my life's work.					
9	I see mathematics as a subject I will rarely use in my daily life as an adult.					
10	Taking mathematics is a waste of time.					
11	In terms of my adult life, it is not important for me to do well in mathematics in high school.					
12	I expect to have little use for mathematics when I get out of school.					

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		Strongly agree	Agree	Neither	Disagree	Strongly Disagree
1	I like mathematics puzzles.					
2	Mathematics is enjoyable and stimulating to me.					
3	When a mathematics problem arises that I cannot immediately solve, I stick with it until I have a solution.					
4	Once I start trying to work on a mathematics puzzle, I find it hard to stop.					
5	When a question is left unanswered in mathematics class, I continue to think about it afterward.					
6	I am challenged by mathematics problems I cannot understand immediately.					
7	Figuring out mathematical problems does not appeal to me.					
8	The challenge of mathematics does not appeal to me.					
9	Mathematics puzzles are boring.					
10	I do not understand how some people can spend so much time on mathematics and seem to enjoy it.					
11	I would rather have someone give me the solution to a difficult mathematics problem than have to work it out for myself.					
12	I do as little work in mathematics as possible.					

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		Strongly agree	Agree	Neither	Disagree	Strongly Disagree
1	Generally, when using a computer, I have felt secure about attempting mathematics.					
2	When using a computer, I am sure I could do advanced work in mathematics.					
3	When using a computer, I am sure I can learn mathematics.					
4	When using a computer in the mathematics classroom, I am still doing mathematics.					
5	When using a computer in the mathematics classroom, I feel as though I am the person who is in control of the answers the computer gives me.					
6	When using computers, I have a lot of self-confidence when it comes to mathematics.					
7	When using computers, I am no good in mathematics.					
8	When using computers, I don't think I could do advanced mathematics.					
9	When using computers, I am not the type to do well in mathematics.					
10	When using a computer in the mathematics classroom, I feel as though I am playing and wasting time.					
11	When using a computer in the mathematics classroom, I feel as though the computer is doing the work for me.					
12	When using computers in mathematics, I become easily frustrated and give up.					

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Appendix D

Appendix D

Example of a Data Analysis Table

What I liked most about doing math on a computer:

Activity	Name	Behaviors	Comment
PowerPoint	Manny	-Spent a great deal of his time fooling around in class. He did not take the activities seriously and was unable to complete all but one assignment.	-It doesn't take a brain to do it.
	Jarek	-Spent a great deal of time searching on the Internet for information I had not located. He was unable to finish the assignment.	-Because (Dave) can't say anything about us looking at cars.
	Martin	-Worked very independently during this activity. He had little interaction with the teachers and completed his assigned work.	-Because you get to use PowerPoint, and you get to go on the Internet, and you get to find plane tickets.
	Allan	-Was much more focused during this activity. He was able to complete half of the PowerPoint assignment.	-I really like doing PowerPoint stuff, and I can look at things that I want to look at.
	Rick	-Had problems staying focused on the work but did better at this activity than the 2nd SS activity or the DB activity.	-Because you don't have formulas to remember.
	Amelia	-Worked well and independently throughout the activity.	-I really like to be able to go to these places.
	Rodriguez	-Worked on his own for the first two classes and then worked with Jarek. He was not too serious about getting work done.	-Because you get to look at cars and stuff.

	Annie	-Worked very well on this assignment with very little teacher help.	-It's funner and easier. You get to look at different places.
	Kate	-Worked very well on this assignment with very little teacher help.	-I like it better because the other activities were, like, you had to find something specific. In this one you get to choose what you want to find.
	Susan	-Was an independent worker, kept on task, helped other students as needed.	-Using PowerPoint is fun, and you just get to explore around the Internet.
	Morgan	- Was very hard working, quiet, didn't help others but did not need much teacher help.	-I like looking at different places that I want to go too.
	Paula	- Was always working, very independent and computer literate.	-Because I like PowerPoint.
	Jeff	-Is very computer literate, spent a lot of time putting in "glitzy" stuff, wants to be a freelance writer or creative writer.	-I didn't find a lot of relevance in those other activities to myself because in my future job I won't need to figure out those formulas a whole lot so maybe just the bills.

	Margot	-Was a very independent worker, helps others when she is finished her work.	-There's more to do on it, and it's not all writing stuff. You get to go through different sites and look at different things.
	Lorne	-Spent a great deal of time in class goofing off and not on task. Is very easily distracted.	-You get to play around and stuff.
	Kristy	-Was an extremely independent worker, helped others with problems, one of the first to finish each activity.	-It's great using the Internet and PowerPoint.
	Kendra	-Was a very independent worker, worked constantly and always on task.	-It doesn't have as much math in it.
	Charlotte	-Was very quiet and afraid to ask questions, asked friends for help, got work completed.	-Being able to look around and being able to choose where we want to go.
First Spreadsheet	Astrid	-Had a very hard time getting any work done. Found using the computers to be very challenging.	-Because it was the easiest, and I kind of understood what was going on.
	Aurora	-Was very teacher reliant to get work done. Was still trying to find tickets when others had already completed the work.	-The first one because it was the easiest.
Second Spreadsheet	Nathalie	-Had a hard time staying focused and is easily discouraged when she gets stuck.	-Because you got to look at souvenirs and stuff. You got to go back and forth to different sites.

	Denise	-Had a very negative attitude towards the activities. Spent a lot of time wasting time. Needed constant help in order to progress.	-Because it was neat getting to look at different catalogues and comparing the prices.

Appendix E

Appendix E

Frequency of Responses Pre-test/Post-test and *Z*-scores

Confidence in Learning Mathematics Scale

		Strongly agree	Agree	Neither	Disagree	Strongly Disagree	Z-score
1	Generally, I have felt secure about attempting mathematics.	4/6	10/11	8/4	1/2		0.2650
2	I am sure I could do advanced work in mathematics.	2/2	10/11	6/6	5/2	0/2	-0.0003
3	I am sure I can learn mathematics.	13/12	8/9	2/2			-0.0977
4	I think that I could handle more difficult mathematics.	2/7	9/10	3/6	9/3	0/2	0.1131
5	I can get good grades in mathematics.	4/5	11/11	4/3	3/3	1/1	-0.0745
6	I have a lot of self-confidence when it comes to mathematics.	4/2	6/9	7/7	5/4	1/1	-0.0003
7	I am no good in mathematics.	2/2	2/2	6/5	9/12	4/2	-0.0320
8	I do not think I could do advanced mathematics.	1/1	8/8	2/2	12/11	0/1	0.0395
9	I am not the type to do well in mathematics.	1/1	4/7	6/3	9/10	3/2	-0.1505
10	For some reason, even though I study, mathematics seems unusually hard for me.	3/6	7/4	0/1	9/8	4/4	-0.0884
11	Most subjects I can handle OK, but I have a knack for flubbing up mathematics.	3/3	3/6	3/2	11/10	3/2	-0.1629
12	Mathematics has been my worst subject.	3/4	1/7	4/1	5/3	10/8	-0.3049

No significant difference at $\alpha = 0.5$.

Usefulness of Mathematics Scale

		Strongly agree	Agree	Neither	Disagree	Strongly Disagree	Z-score
1	I will need mathematics for my future work.	4/3	10/8	7/6	1/2	1/3	-0.3154
2	I study mathematics because I know how useful it is.	2/2	6/5	8/9	7/5	0/2	-0.1392
3	Knowing mathematics will help me earn a living.	2/5	15/11	5/3	0/2	1/2	-0.1328
4	Mathematics is a worthwhile and necessary subject.	2/2	12/13	5/5	3/1	1/2	0.0443
5	I will need a firm mastery of mathematics for my future work.		4/10	15/6	4/4	0/3	0.0000
6	I will use mathematics in many ways as an adult.	3/5	15/12	3/2	2/4		-0.0712
7	Mathematics is of no relevance to my life.		4/3	8/7	10/11	1/2	0.2518
8	Mathematics will not be important to me in my life's work.	0/2	2/4	7/5	12/8	2/4	-0.4255
9	I see mathematics as a subject I will rarely use in my daily life as an adult.	0/2	3/2	5/6	13/10	2/3	-0.2469
10	Taking mathematics is a waste of time.	0/1	1/2	6/4	13/11	3/5	-0.0805
11	In terms of my adult life, it is not important for me to do well in mathematics in high school.		1/2	6/5	13/11	3/5	0.0801
12	I expect to have little use for mathematics when I get out of school.	0/2	3/5	6/2	11/10	3/4	-0.2740

No significant difference at $\alpha = 0.5$.

Effectance Motivation in Mathematics Scales

		Strongly agree	Agree	Neither	Disagree	Strongly Disagree	Z-score
1	I like mathematics puzzles.	1/1	4/5	7/5	7/5	4/3	0.0699
2	Mathematics is enjoyable and stimulating to me.	0/1	4/4	7/6	10/7	2/1	0.2166
3	When a mathematics problem arises that I cannot immediately solve, I stick with it until I have a solution.	2/1	8/5	7/6	6/7		-0.1409
4	Once I start trying to work on a mathematics puzzle, I find it hard to stop.		2/4	5/2	15/10	1/3	0.0003
5	When a question is left unanswered in mathematics class, I continue to think about it afterward.	3/1	9/9	4/3	5/8	2/2	-0.2061
6	I am challenged by mathematics problems I cannot understand immediately.	4/1	9/12	6/4	4/4	0/1	-0.1323
7	Figuring out mathematical problems does not appeal to me.	0/2	5/3	5/6	11/7	2/1	0.3280
8	The challenge of mathematics does not appeal to me.	0/1	4/5	7/6	9/8	3/3	-0.0940
9	Mathematics puzzles are boring.	5/5	5/4	7/5	3/7	3/1	0.0216
10	I do not understand how some people can spend so much time on mathematics and seem to enjoy it.	5/4	7/7	4/4	6/5	1/3	0.1005
11	I would rather have someone give me the solution to a difficult mathematics problem than have to work it out for myself.	4/1	4/2	6/4	6/10	3/2	0.2264
12	I do as little work in mathematics as possible.		2/2	5/5	11/8	5/4	-0.0956

No significant difference at $\alpha = 0.5$.

Confidence in Learning Mathematics with Computers Scale

		Strongly agree	Agree	Neither	Disagree	Strongly Disagree	Z-score
1	Generally, when using a computer, I have felt secure about attempting mathematics.	0/3	8/10	12/4	1/1	2/1	0.4604
2	When using a computer, I am sure I could do advanced work in mathematics.	3/2	4/9	11/6	4/1	1/1	-0.1642
3	When using a compute, I am sure I can learn mathematics.	2/4	8/8	9/5	3/1	1/1	0.3212
4	When using a computer in the mathematics classroom, I am still doing mathematics.	2/1	8/11	10/5	2/1	1/1	0.2486
5	When using a computer in the mathematics classroom, I feel as though I am the person who is in control of the answers the computer gives me.	0/1	5/5	13/9	4/3	1/1	0.2946
6	When using computers, I have a lot of self-confidence when it comes to mathematics.	0/3	8/5	10/7	3/2	2/2	0.1515
7	When using computers, I am no good in mathematics.	1/1	3/1	9/4	10/11	0/2	0.6617
8	When using computers, I don't think I could do advanced mathematics.	1/1	6/2	6/4	9/10	1/2	0.2536
9	When using computers, I am not the type to do well in mathematics.	1/1	4/1	7/4	11/10	0/3	0.3741
10	When using a computer in the mathematics classroom, I feel as though I am playing and wasting time.	1/2	6/1	7/0	8/13	0/3	0.5262
11	When using a computer in the mathematics classroom, I feel as though the computer is doing the work for me.	2/2	5/7	9/6	7/3	1/1	-0.4339
12	When using computers in mathematics, I become easily frustrated and give up.	3/2	2/2	8/5	9/5	1/5	-0.0004

No significant difference at $\alpha = 0.5$.

Appendix F

Appendix F

Research Timeline

Date	Activity	Comments
February – March	Prepared the unit of instruction	
March 15	Administered the survey	Remained to observe the students
March 19	Activity 1	Both periods in the computer lab
March 25	Activity 2	Both periods in the computer lab
March 26	Activity2	First class in the regular classroom, second class in the computer lab
April 1	Activity 2	Both periods in the computer lab
April 15	Activity 3	First class in the regular classroom, second class in the computer lab
April 22	Activity 4	First class in the regular classroom, second class in the computer lab
May 6	Activity 4	Both periods in the computer lab
May 13	Activity 4	PowerPoint presentations
May 17	Administered the survey	
May 18	Student Interviews	